STUDIES ON THE PLANT PARASITIC NEMATODES ASSOCIATED WITH SOME ORNAMENTAL PLANTS

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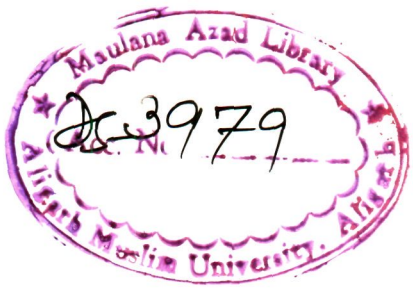

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Dedicated

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Certificate

This is to certify that the work presented in this dissertation entitled ***"Studies on the Plant Parasitic Nematodes Associated with Some Ornamental Plants"*** is an original piece of work carried out by ***Miss. Aasia Rashid Bhat*** under my guidance and supervision and has not been submitted elsewhere for the award of any other degree and can be submitted in partial fulfilment of the requirements for the award of the degree of ***Master of Philosophy*** in ***Botany (Plant Pathology).***

(Tabreiz Ahmad Khan)
Supervisor

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I bow in reverence to Almighty God, the most merciful who showered His gracious blessing upon us, showed me path of righteousness and enabled me to achieve this target.

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Introduction

INTRODUCTION

The soil constitutes a complex ecosystem that harbours a wide variety of plants and pathogenic organisms such as bacteria, fungi, actinomycetes, insects and nematodes etc; which make its biological system. Out of these organisms which inhabit the soil ecosystem, the plant parasitic nematodes are the most important ones which constitute about 12% of the soil flora and fauna. These are found around the roots of plants and are said to play a vital role in their growth and production. On our globe rarely is any crop free from their attack, yet we are unaware of their appearance because of their microscopic size and protected position in the soil. These active slender worm like creatures are found not only inhabiting the soil but also in fresh and salt water wherever organic matter exists.

Nematodes constitute the largest and the most ubiquitous group of animal kingdom comprising about 80-90% of all the multicellular animals. Nematodes cause an estimated annual loss of about 12% of all major crops costing nearly 8 billion US dollar annually in the United States and 78 billion US dollar per year world wide (Sasser and Freckman, 1987).

Plant parasitic nematodes have been recognized as one of the limiting factors in the normal production of vegetable crops and ornamental plantations all over the world. Plant parasitic nematodes affect the production and economy of crop in diverse ways such as reduction in quality and quantity of crop, application of nematicides and impediment of production and trade by phytosanitary regulations (Weischer, 1968). Among phytonematodes, root-knot nematodes (*Meloidogyne* spp.) are one of the most important pest that parasitize most crop plants including ornamentals. Ornamental plants which are grown to decorate parks, gardens and homes like other crops also have a wide nematode fauna which causes tremendous economic losses. There are some reports of crop losses in terms of money. A loss of 5 million kroners was estimated due to cereal cyst nematode, *Heterodera avenae* in Denmark (Stapel, 1953). USDA estimated an annual crop loss of 372, 335000 dollars to sixteen crops (Taylor, 1967). In other estimates, Hutchinson *et al.* (1961) and Cairns (1955) reported loss of $ 250 million and $ 500 million due to nematodes. The estimated annual loss due to nematodes in USA was of the order of $ 10, 38,374,300 in 16 field crops, $ 225,145,900 in fruits and nut crops, $ 266,289,100 in

vegetable crops and $ 59,817,634 in ornamental crops (Feldmesser *et al.*, 1971). In a world wide survey conducted by Sasser (1989), the most important genera of plant parasitic nematodes revealed were *Meloidogyne, Pratylenchus, Heterodera, Ditylenchus, Globodera, Tylenchus, Xiphinema, Radopholus, Rotylenchulus* and *Helicotylenchus.* This order of importance of various genera was found to be respective for most regions of the world.

In India, the annual loss inflicted by pests, nematodes and weeds is estimated at Rs. 6,000 – 17,000 crores. Many workers have attempted to assess the crop losses caused by plant parasitic nematodes in India. Van Berkum and Seshadri (1970) have calculated these losses in India in terms of money. They estimated the annual losses due to 'ear cockle' disease caused by *Anguina tritici* on wheat at $ 10 million, due to *Pratylenchus coffeae* on coffee at $ 3 million and due to molya disease caused by *Heterodera avenae* in Rajasthan alone at $ 8 million. Paruthi and Bhatti (1981) reported the loss in wheat yield due to *Anguina tritici* ranged from 1 - 9%. Some important nematode pests are potato cyst nematode, *Globodera rostochiensis* in the Nilgiris, the citrus nematode, *Tylenchulus semipenetrans* in citrus crops, the burrowing

nematode, *Radopholus similis* in banana and the reniform nematode, *Rotylenchulus reniformis* in cotton, maize, ginger, millet, cowpea, and blackgram. The loss in wheat yield was up to 42.2% in the sandy soil of Rajasthan due to *Heterodera avenae* (Mathur *et al.*, 1986). Jain *et al.* (2007) revealed that maximum loss to the extent of 4779.00 million rupees in rice due to *Meloidogyne graminicola, Heterodera oryzicola* and *Aphelenchoides besseyi* occurring in different rice growing areas of India. Moreover, the national loss due to plant parasitic nematodes in 24 different crops in monetary terms has been reported to the tune of 21068.73 million rupees which needs due attention so as to work out effective nematode management technologies for reducing the losses caused by plant parasitic nematodes.

Production and planting of ornamentals in landscapes is a multi-billion dollar industry in Southeastern U.S.A. In this region, nematodes are important pests of ornamental plants, and while several genera of nematodes cause disease, *Meloidogyne* spp. (root-knot nematodes) are particularly damaging (Nemec and Struble, 1968; Benson and Barker, 1985; Williams-Woodward and Davis, 2001). Sanitation, plant resistance, chemical control and exclusion of infected materials

are common methods for preventing infection of plants by nematodes (Dunn and Crow, 2001). Selecting and planting non-hosts or tolerant species, therefore, will benefit the ornamental plant industry and consumers alike. In India, cultivation of ornamental plants is mainly practiced in Southern States especially in Tamil Nadu and Karnataka as these shares for more than 50% of cultivation in acreage. Indian domestic market for flower is worth Rs.250 crores and export is about Rs. 14 crores. Despite having so much potential in the floriculture, cultivation of these products also suffers with constraints like pest and diseases which includes plant parasitic nematodes. Since the value of the flower and other decorative plants is viewed only by its beautiful appearance along with quality and free from any ailments. Therefore, floriculture is an input intensive agriculture. In Uttar Pradesh, some information has been generated on the distribution of plant parasitic and other soil nematodes associated with different food crops (Rashid *et al.*, 1973). Commercial floriculture, especially cut flowers, has proved to be high value cash cropping, being adopted extensively in open fields and polyhouses for export purpose. Apart from several biotic stresses that reduce production of cut flowers,

infection by plant parasitic nematodes poses several problems like reduction in flower yield and quality, which ultimately decline the market value of crops (Choi *et al.*, 1992).

Ornamentals like other crops harbour a multitude of nematode fauna, viz. *Ditylenchus dipsaci,* responsible for completely wiping out of narcissus industry in U.K; *Meloidogyne* spp. on gladioli; *Aphelenchoides ritzemabosi, Belonolaimus longicaudatus* and *Trichodorus* sp. on chrysanthemum in U.S.A.; *Xiphinema diversicaudatum* on roses in Western Europe have been listed as the major nematode resulting in considerable growth reduction (Hague, 1972; Southey, 1993). The damage to ornamental plants and low yields caused by plant parasitic nematodes frequently unrecognized or attributed to other causes.

The study of plant parasitic nematodes of ornamental plants has received little attention in India. Most of the information on association of nematodes to ornamental plants is quoted from the work done abroad.

Keeping in view the importance of ornamental plants and association of plant parasitic nematodes with these plants, the following aspects were conducted:

(1) Survey of plant parasitic nematodes associated with ornamental plants.

(2) Occurrence of root-knot and reniform nematodes in ornamental plants grown in the campus of A.M.U.

(3) Studies on the pathogenicity of root-knot nematode (*Meloidogyne incognita*) on *Pseuderanthemum atropurpureum.*

(4) Studies on the pathogenicity of reniform nematode (*Rotylenchulus reniformis)* on *Coleus blumei.*

(5) Studies on the pathogenicity of spiral nematode (*Helicotylenchus dihystera)* on *Celosia cristata.*

Review of Literature

REVIEW OF LITERATURE

One of the earliest records of a nematode fauna of an ornamental plant may be that of Prillieux (1881) who described nematode disease of hyacinths caused by *Ditylenchus dipsaci*. Thereafter, according to Goodey (1933) important studies were made on *D. dipsaci* and *Aphelenchoides* spp. on bulbs and ornamental plants in the Netherlands by Ritzema Bos in the late 1880s and 1890s and *D. dipsaci* on phlox by Nypels (1898). Marcinowski's classic monograph (Marcinowski, 1909) describes many nematode/host-plant association including *D. dipsaci* on hyacinth, phlox and others, *Aphelenchoides* sp. on numerous ferns and ornamental plants, and *Meloidogyne* sp. on ornamental plants, both glasshouse and outdoor.

Goff (1936) was one of the first researchers to conduct an extensive survey of the susceptibility of ornamental plants to *Meloidogyne* spp. In his survey, Goff noted the varying degrees of susceptibility among the tested plant species. Root-knot infected plants often exhibit symptoms that include root-galls and root- rots, yellowing and chlorosis of shoot, stunted growth and other symptoms commonly associated with

nutritional deficiencies (Bird, 1974; Santo and Lear, 1976; Zarina and Abid, 1995; Bala and Hosein, 1996; Misra *et al.*, 2002) resulting in general decline (Nigh, 1972), poor yield (Rajendran *et al.*, 1975). Furthermore, reduction in photosynthetic rate has also been observed in response to root-knot nematode infections. Often, the ratio of food resources provided by the host plant and the root-knot nematode density determines the degree of host response to infection (Bird, 1974). However, Walker and Melin (1998) observed greater plant growth in the presence of low plant-parasitic nematode populations than in their absence. Certain ornamentals infected with root-knot nematodes exhibit unique symptoms. Such plants include *Sansevieria cylindrica*, which developed leaf discoloration and tip necrosis 4 to 5 months post-infection with *M. incognita* (Misra and Mishra, 1997), *Philodendron selloum*, which exhibits a reduction in leaf size when infected with *M. incognita* (Mishra and Misra, 1993), and *Juniperus horizontalis* var. *Plumosa* and *Thuja oreintalis* cv-Dwarf Greenspike, which exhibit thickened roots and slight galling post-infection with *Meloidogyne* spp. (Nemec and Morrison, 1972). Furthermore, *Gladiolus hortulanus* plants infected with *M. incognita* race 2 exhibited leaf drying,

reduction in floral stalk height and girth, and reduced number of florets (Khanna *et al.,* 1998).

Mixed populations of *Meloidogyne* spp. are often observed parasitizing perennial ornamentals. Mixed populations of *M. javanica* and *M. incognita* have also been observed to infect *Rosa indica* (Zarina and Abid, 1995).

La Mondia (1995, 1996) conducted an extensive study and evaluated the susceptibility of an array of perennial herbaceous ornamentals against *M. hapla*. Approximately 30% of tested perennials were resistant to the isolate evaluated.

Plant parasitic nematodes have been recognized as one of the limiting factors in the production of ornamental plants all over the world. Ornamental plants are grown for fragnance and beautification. In U.S.A., losses in ornamental due to nematodes were estimated to the tune of $ 60 million annually (Hague, 1972). Sasser and Freckman (1987) reported that throughout the world in ornamental crops, plant parasitic nematodes are responsible for 11.1% losses. Among the plant parasitic nematodes, *Meloidogyne* spp. the causal agent of root-knot disease, causes serious damage to ornamental and foliage plants. The other principal nematodes infesting ornamental plants are stem and bulb nematodes (*Ditylenchus*

dipsaci and *D. destructor)*, leaf and bud nematodes (*Aphelenchoides ritzemabosi* and *A. fragariae)* and root- lesion nematodes, *Pratylenchus penetrans* (Southey, 1993).

Celosia cristata L. occurs in worm countries mainly in the tropics and subtropics. It is cultivated not only as an ornamental, but used as a vegetable and pot-herb in many Western African countries. Caveness and Wilson (1977) observed that *M. incognita* and *M. javanica* readily attacked *C. argentea*, significantly reduced its early, rapid growth. At harvest, 74 days after emergence, all plants grown in root-knot infested soil were significantly smaller than plants grown in fumigated soil and roots were heavily galled indicating that this cultivar was highly susceptible to the nematodes. As an economic crop, it is suggested that *C. argentea* needs to be grown in a rotation regime in which the plant parasitic nematode population are kept below damage inflicting thresholds.

Haseeb *et al.* (1981) conducted an investigation on *M. incognita* infested and uninfested cock's-comb roots for the presence of saponin, phytosterol, alkaline oxidase and catalase. They observed that no reaction for phytosterol,

alkaline oxidase and catalase occurred in infested roots where as healthy roots reacted positively.

Economically, chrysanthemum is one of the most valuable ornamental plant grown throughout the world. *Chrysanthemum* spp. are attacked by *Paralongidorus maximus* (Sturhan, 1963, 1975), *Pratylenchus projectus* (Brzeski and Szezygiel, 1963), *Heterodera mothi* (Khan and Hussain, 1965), *Meloidogyne javanica* (Chandwani and Reddy, 1967), *Aphelenchoides ritzemabosi* (Gill and Sharma, 1967), *Rotylenchulus reniformis* (Swarup *et al.*, 1967), *Aphelenchoides besseyi* (Hussey *et al.,* 1969), *Belonolaimus longicaudatus, Trichodorus* sp., *Meloidogyne* sp. (Hague, 1972), *Tylenchorhynchus vulgaris* (Upadhyay and Swarup, 1972), *Pratylenchus coffeae* (Rashid and Khan, 1975), and *P. penetrans* (Ferraz and Monteiro, 1983; Amsing, 1987).

In India, Edward *et al.* (1969) reported *Pratylenchus chrysanthus* associated with root-rot of chrysanthemum. Kobayash *et al.* (1974) in Japan found the association of *P. fallax* with successive growth failures of this crop.

Pathogenicity of *Aphelenchoides ritzemabosi* investigated by Mcleod (1981) on chrysanthemum. Netherlands (1986) reported another nematode, *Pratylenchus penetrans* on

chrysanthemum attacking root and causing root lesions which lead into decreased root weight and shoot growth.

Akhtar (1962) reported *Chrysanthemum* sp., from Lahore as a new host for *Paratylenchus* sp., and *Xiphinema americanum.* Kafi (1963) listed different nematodes from various ornamental plants where *Aphelenchoides* sp., *Paratylenchus* sp., *Tylenchorhynchus* sp., and *Xiphinema americanum* were found from the rhizosphere of *Chrysanthemum* sp., *Aphelenchoides* sp. and *Hemicycliophora* sp. were found around the roots of *Celosia argentea* from Lahore, *Pratylenchus coffeae* and *Rotylenchulus reniformis* on the roots of *Codiaeum variegatum* and *Pratylenchus* sp. from the rhizosphere of *Hibiscus rosa-sinensis; Ditylenchus* sp., *Helicotylenchus dihystera* and *Tylenchorhynchus* sp. from the rhizosphere of *Cynodon dactylon* from Karachi.

Marwoto and Rohana (1986) reported that the *Meloidogyne* sp., *Pratylenchus* sp., *Helicotylenchus* sp. and other species of Tylenchida infested the chrysanthemum planted soil at a density of 32, 22, 10 and 20 nematodes/100 g soil at Lembang and Pacet, Indonesia. The highest yield loss due to nematodes was found in Sindanglaya (Pacet) 29% and Patrol (Lembang) 27.5%.

Among the ornamental plants, roses (*Rosa indica*) have been found to be severely damaged by *Meloidogyne hapla* (Anon, 1968;Johnson *et al.*, 1969), *M. arenaria, M. hapla, M. incognita* and *M. javanica* (Kinshakova, 1969), *Paratylenchus hamatus* (Mac Donald, 1976), *P. vulnus* (Santo and Lear, 1976), *Paratylenchus, blothrotylus* (Baldwin and Bell, 1981), *P. penetrans* (Amsing, 1988), *Pratylenchus* sp. and *Helicotylenchus* sp. (Sundarababu and Vadivelu, 1989). Association of *Pratylenchus vulnus* with the stunting and chlorotic condition of rose plant was achieved by Schindler (1956), which was corroborated by Sher (1957). Schindler (1957) also reported unproductive flower and increase susceptibility of rose to other diseases due to infestation of *Xiphinema diversicaudatum.*

Prasad and Dasgupta (1964) isolated fifteen nematode species from the rhizosphere of rose. Out of which, *Hoplolaimus galeatus, Xiphinema diversicaudatum, Helicotylenchus nannus, Tylenchorhynchus dubius, Pratylenchus pratensis* and *Hemicycliophora typica* were the most frequently encountered species.

Muthukrishnan *et al.* (1975) considered *Hemicycliophora labiata* and *Xiphinema basiri* as the potential causative agents for unproductive flowers of *Rosa chinensis.*

Sunderababu and Vadivelu (1988) observed the pathogenicity of *Pratylenchus zeae* on Edward Rose and found that *P. zeae* even at low inoculum level caused 72% reduction in weight. Singh and Kumar (2002) recorded nine species of plant parasitic nematodes from the rhizosphere of roses grown in Mehrauli block of Delhi. Out of which *Helicotylenchus indicus, Xiphinema diversicaudatum, Tylenchorhynchus vulgaris* and *Tylenchus* spp. were the most predominant nematode associated with roses.

Jasmine (*Jasminum* spp.) is grown both for its flowers as well as oil. In Karnataka alone it is cultivated over an area of 2307ha. *Meloidogyne incognita* was reported on *Jasminum sambac* and *J. flexile* by Rajaram and Rajendran (1979). They also observed that infected plants often showing pale coloured leaves and die-back symptoms.

Bajaj (1989) recorded *Tylenchulus semipenetrans* on *J. sambac* from Haryana. Khan and Reddy (1989) recorded high population of *Radopholus similis* from stunted *J. pubescens* plants in Bangalore. *Jasminum sambac* was inoculated in a pot

experiment with *Pratylenchus delattrei, Helicotylenchus dihystera* and *Hoplolaimus seinhorsti* at 10, 100, 1000 or 10,000/pot. Plant growth was affected by all the 3 nematodes which were pathogenic at 100 nematodes/pot or over. (Sundarababu and Vadivelu, 1990).

Incidence of gladiolus scab caused by *Pseudomonas marginata* was found in the presence of *M. javanica* (Elgoorani *et al.,* 1974). Reddy *et al.* (1979) reported that *M. incognita* causing heavy damage to the crop. They also noticed the heavy galling on roots resulting in yellowing of leaves which subsequently leads to stunted growth of the plant. Khanna (1996) showed that gladiolus cv. Vinks Glory, inoculated with different population levels (10, 100, 1000 and 10, 000) of J_2 of *M. incognita* showed adverse plant growth in pot experiments. Ravishankar and Singh (2007) studied the pathogenicity of root-knot nematode (*M. incognita*) to gladiolus and revealed that with an initial nematode inoculum level from 10 to 10,000, there was a corresponding and progressive reduction in all the plant growth parameters and also multiplication in soil and root population of nematode. Waliullah *et al.* (2007) conducted a survey on plant parasitic nematodes associated with *Gladiolus hortulans* in Srinagar district of Jammu and

Kashmir, India. It was noted that the root-knot nematode, *Meloidogyne incognita* was the most prevalent nematode followed by *Paratylenchus* spp., *Helicotylenchus dihystera* and *Paratrichodorus* spp. The growth parameters such as shoot and root length as well as number of leaves were significantly reduced in the infested plants. In this survey, six gladiolus cultivars viz. American beauty, White friendship, Apple blossom, Rose spring and Snow princess were screened for the prevalent nematodes. All the cultivars showed high susceptibility to nematodes infestation except white friendship.

Tuberose (*Polianthus tuberosa*) is grown over an area of 655ha in Karnataka. Melis (1959) described *Meloidogyne* spp. as an important pest of tuberose. Other nematodes reported on tuberose include *Aphelenchoides besseyi, Belonolaimus longicaudatus* and *Trichodorus* sp. (Overman, 1970). In India, Jayaraman *et al.* (1975) found root-knot as the major factor in tuberose decline. Kumar *et al.* (1987) reported galls of *M. arenaria* on the underside of leaves of *Polianthes tuberosa.* Sundrababu and Vadivelu, (1988) reported *M. incognita, M. javanica* and *M. arenaria* on tuberose from Tamil Nadu.

Srinivasan (1974) recorded lesion nematode, *Pratylenchus delattrei* on crossandra. Other important

nematode infecting *Crossandra* spp. is root-knot nematode, *M. incognita* (Rajendran *et al.,* 1976), *Longidorus africanus* (Vadivelu *et al.,* 1976, Muthukrishnan *et al.,* 1977). Srinivasan and Muthukrishnan (1975) confirm that *Pratylenchus dellatrei* is highly pathogenic to *Crossandra undulaefolia*.

Plant parasitic nematodes found associated with carnations are *Paratylenchus* sp. and *Criconemoides xenoplax* (Sher, 1959), *Paratylenchus projectus* (Brzeski and Szezygield, 1963), *Heterodera trifolli* (Cuany and Dalmasso, 1975; Balbaeva and Zelikov, 1980). Batyr and Lisetkaya (1980) described the population dynamic of *M. arenaria* in the rhizosphere of carnation. Kim *et al.* (1987) found that the species of *Pratylenchus*, *Paratylenchus* and *Tylenchus* were most pathogenic to carnation in which *Paratylenchus* spp. population was as high as 3500 nematodes/300 cc soil. Other nematodes such as *Ditylenchus dipsaci, Heterodera trifolli, Paratylenchus dianthus* and *Criconemella curvata* also attack carnation (Lamberti *et al.,* 1987).

Hibiscus rosa-sinensis is known to harbour the populations of *Pratylenchus* sp. (Kafi, 1963), *Rotylenchulus reniformis* (Swarup *et al.,* 1967), *Tylenchorhynchus chonai* (Sethi and Swarup, 1968), *Aphelenchoides ritzemabosi*

(Boesewinkel, 1977), *M. javanica* and *M. incognita* (Mescorley and Marlatt, 1983) and *Helicotylenchus varicaudatus* (Karepetyan, 1984).

Criconemoides kamalli was described from the rhizosphere of *Bougainvillea* sp. (Khan, 1971) from Karachi which has now been placed under species inqurindae by Siddiqi (1986). Similarly, Haseeb *et al.* (1978) and Khan *et al.* (1980) reported *Hoplolaimus indicus, Helicotylenchus indicus, Rotylenchulus reniformis, M. incognita* and *Aphelenchus absari* from rhizoshpere of *Bougainvillea spectabilis*.

Swarup *et al.* (1967) recorded *Rotylenchulus reniformis* on *Thevetia peruviana.* Mead (1987) recorded *Longidorus* sp. *Scutellonema brachyurum* and *Xiphinema americanum* on *Thevetia peruviana.* Eastern lilies are severely damaged by *P. penetrans* (Jenson, 1961). Cayrol and Ritter (1962) described severe damage to *Convallaria majalis* cv. by *Pratylenchus convallariae* occurring in most regions of France where this plant is grown. This nematode causes typical root lesions followed by rapid destruction of cortex and phloem.

Pratylenchus penetrans is also important pest of narcissus (Seinhorst, 1957), besides *Ditylenchus dipsaci* on

narcissus and tulip and *Aphelenchoides subtenius* on tulip and narcissus (Caubel, 1976). Apt and Gould, (1961) and Lane (1984) reported that the narcissus root-rot caused by *P. penetrans* which ultimately reduced the production of narcissus flowers in England. In Netherlands, root damage associated with *P. penetrans* and weakly parasitic fungi occasionally occur on tulip, hyacinth, iris, and gladiolus and *Lilium* sp. on sandy soils. Attack on *L. regale*, *L. speciosum* and *L. tigrinum* affect bulb scales as well as roots (Mass *et al.*, 1978; Bakker, 1981).

Edwards (1937) described serious out break of *Ditylenchus dipsaci* on cultivar of *Primula* spp. and reported 34 species of Primula as hosts.

Surveys of plant parasitic nematodes on woody ornamentals were common since last 20 to 30 years ago (Davis and Jenkins, 1960; Mai *et al.*, 1960; Haasis *et al.*, 1961; Stessel 1961; Wilson and Walker, 1961; Springer, 1964; Birchfield *et al.*, 1978; Barker *et al.*, 1979). Although root-knot nematodes were not always the most frequently found parasitic nematode, their mere presence on so many different plant species led to research on possible chemical controls because of potential for plant damage (Walker and

Wilson, 1962; Heald and Jenkins, 1964; Miller and Perry, 1965; Harlan and Jenkins, 1967; Taylor and Sasser, 1978; Johnson and Feldmesser, 1987).

A wide variety of woody ornamental species are produced in the Southern United States, and information is available on reaction of some ornamentals to root-knot nematodes. Root-knot nematodes were discovered on gardenia than a century ago (Lehman, 1984) causing disruption of the cortical root tissue, similar to that in crop plants (Davis and Jenkins, 1960) resulting in decline of plant vigour.

Ilex spp. are prevalent in Southeastern landscapes and certain species are known hosts for root-knot nematodes (Heald 1967; Aycock *et al.,* 1976; Barker *et al.,* 1979; Benson and Barker, 1982; Stokes, 1982; Bernard *et al.,* 1994). Barker *et al.* (1979) observed that the Japanese hollies (*Ilex crenata)* are highly susceptible to root-knot nematode (*M. arenaria, M. hapla, M. incognita, M. javanica* and *M. incognita acrita*, whereas Chinese holly (*I. cornuta)* and dwarf yaupon holly (*I. vomitoria)* are tolerant.

Temperature and other weather factors also greatly influenced the population of different plant parasitic nematodes (Saeed, 1974; Gul, 1988). Saeed and Ghaffar

(1986) studied the seasonal fluctuation of *Hemicriconemoides mangiferae* in sapodilla (*Achras zapota)* where 2 populations March-April and the other in October-November with a decline in June and July have been reported.

Krishnappa *et al.* (1980) conducted a survey on plant parasitic nematodes associated with ornamental plants in Bangalore. The most widely distributed nematodes were *Rotylenchulus reniformis* and it was followed by *Meloidogyne incognita, Helicotylenchus crenatus, Tylenchus* sp. and *Hoplolaimus indicus*.

Bensen and Barker (1982) investigated the effect of *Meloidogyne arenaria, Pratylenchus vulnus, Tylenchorhynchus claytoni* and *Criconemella xenoplax* on six plants such as Japanese boxwood, dwarf gardenia, compacta holly, spring greek, junipers and observed root galling and stunting on Japanese boxwood. Susceptibility of Japanese holly to root knot, stunt and ring nematodes was experimentally proved first time by Bensen *et al.* (1982), whereas, azalea and rhododendron were found to be non-host.

Haider and Khan (1986) conducted a survey of the ornamental plants viz. *Impatiens balsamina, Petunia alba, Portulaca grandifolia* and *Celosia grandifolia* in Uttar Pradesh.

They found that *M. javanica* and *M. incognita* were the dominant species of root – knot nematodes.

Maqbool *et al.* (1986) conducted a survey on root-knot nematodes in Karachi and its adjoining areas and recorded 11 new hosts of root-knot nematodes (*Meloidogyne* spp.) namely: cactus (*Opuntia* sp.), ceriman (*Monstera deliciosa*), cock's comb (*Celosia argentea*), dumb cane (*Dieffenbachia seguine*), milkbush (*Euphorbia tirucalli*), purslane (*Portulaca oleracea*), red spinach (*Amarnathus hybridus*) and spider plant (*Chlorophytum cosmosum*).

Pinochet and Durate (1986) tested 46 species of ornamentals against *Pratylenchus coffeae,* out of which *Ficus elastica, Hippestrum vitattum, Peperomia* spp. and *Zebrina pendula* were good hosts.

Parasitism on roots of *Abelia grandiflora, Cornus floride, Paniculata, Photina* and *Spiraea* by *M. hapla* showed galls and eggmasses on roots (Bernard and Witte, 1987). Derrico *et al.* (1987) reported a species of *Heterodera*, which is morphologically similar to *H.daverti* damaging carnation in Italy. Khan *et al.* (1987) surveyed datepalm in Baluchistan and observed that the *Pratylenchus nainianus* was predominant.

Vazquer and Fernandez (1987) found 15 plant parasitic nematodes from the rhizosphere of 25 ornamental species at Cuba. Gul (1988) reported *Ditylenchus dipsaci* around the roots of *Tulip* sp., and *Hyacinth* sp., while *M. incognita* was found in N.W.F.P on *Convollaria majalis*. Atleast 19 species belonging to 13 genera of parasitic and non parasitic nematodes were detected by Saeed *et al.* (1988) from the rhizospheric soil of *Rosa damascena* from Karachi area. Amaranatha and Krishnappa (1989) studied the effect of different inoculum levels of *Meloidogyne incognita* on sunflower. They observed that as the population density of nematodes increased, plant growth decreased. They also showed that inoculation of 10,000 juveniles of *M. incognita* per plant proved to be the damage threshold level and plants at this level exhibiting stunting, yellowing and drooping of leaves.

Anwar (1989) detected *Criconemoides* sp., *Pratylenchus* sp., and *Tylenchorhynchus* sp. around the roots of *Chrysanthemum* sp., and *Aphelenchoides ritzemabosi* from the leaf of *Chrysanthemum* sp. Stephan (1989) reported first time *Ditylenchus dipsaci* on alfalfa (lucerne), *Dianthus caryophyllus* and *Gladiolus palustris* from Iraq.

Narbaev and Mirsalimora (1989) found the infection of *Meloidogyne incognita, M. arenaria* and *M. javanica* on ornamentals grown in greenhouses in Botanical gardens of Academy of Science of Uzbek SSR in Tashkent, USSR.

Mc sorely and Dunn (1990) conducted the studies to determine the effects of *Meloidogyne* spp. on five species of perennial ornamentals used in the Florida landscape, as well as the ability of these hosts to support nematode reproduction. They observed that the inoculation of *Photinia fraseri* and *Ilex cornuta* cv. Burfordi with *M. arenaria, M. incognita* races 1 and 3, or *M. javanica* resulted few galls and no recovery of eggs from roots systems. Similar results were obtained on *Dracaena marginita* except *M. javanica,* which produced a moderate level of galling whereas *Meloidogyne* spp. cause severe galling and produced large no of eggs on *Ficus benjamina* and *Ajuga reptans*. None of the five tested hosts showed the reductions in shoot or root weight due to inoculation of *Meloidogyne* spp. Sun *et al.* (1990) during the survey on root knot disease of ornamental plants in Lianyungang city, Jiangsu Province, China investigated that among the 212 species of plants, 41 species were infected by *M. incognita M. arenaria, M. javanica* and *M.*

hapla. About 16 host plants found a new host record of *M. incognita*.

Amaranatha and Krishnhappa (1990) reported that *Rotylenchulus reniformis* was the most predominant associated nematode with sunflower in Karnataka. Out of 33 commonly planted horticultural crops tested in a pot experiment for their host status to *Meloidogyne incognita;* 10 were non-hosts, while *Celosia hybridus* and *Coleus* sp. were excellent hosts (Fademi, 1990). Khanna and Khan (1990) reported that *Helicotylenchus vericaudatus* and *Tylenchorhynchus mashhoodi* were widely distributed nematode species associated with ornamental plants in India.

Montasser (1990) collected root samples of cultivated ornamental plants from different nurseries and greenhouses in Egypt. Twenty three non-crop plant species belonging to 8 families were found to be infected with *M. incognita*. Gall indices ranged from 2 to 5 and eggmass indices from 1 to 5. These ornamental plants are new host for *M. incognita* in Egypt.

Amsing (1991) reported that very low populations of *Pratylenchus vulnus* significantly reduced the root and flower production of both varieties of roses (Multic and Inermis).

Singh and Majeed (1991) revealed that 30 percent annuals did not show infestation at all and rated as resistant, 26 percent yielded infestation in pots only, while, 44 percent developed infestation under both conditions. The results further suggest that susceptible annuals be rotated with resistant ones and should not be planted in the same piece of land year after year.

Choi *et al.* (1992) showed that the fresh weight of gerbera reduced by 65%, 76% and 85% at different inoculum level of *Pratylenchus coffeae* (1000, 5000 and 10,000 nematodes per plant) and number of flowers also decreased by 81% and 95% at 1000 and 5000 nematodes per plant, respectively. Cadet *et al.* (1992) during the course of survey of plant parasitic nematodes in various plantations of ornamentals in Martinique revealed heavy infestations of *M. arenaria* in *Alpinia* sp., *M. incognita* in standard and *Radopholus similis* in *Anthurium* spp. and of *Pratylenchus coffeae* in *Alocasia* sp.

Shakeel (1992) found *Hemicriconemoides* sp. and *Quinisulcius* sp. on *Rosa indica*, whereas, *Aphelenchus* sp., *Helicotylenchus* sp., *Hoplolaimus* sp., *Quinisulcius* sp.,

Rotylenchulus sp., *and Pratylenchus* sp., were found on *Jasminum sambac* from Pakistan.

Ismail and Eissa (1993) reported association of plant parasitic nematodes with ornamental palms in Egypt. The dominant nematode genera were *Criconemoides, Ditylenchus, Helicotylenchus* and *Rotylenchulus reniformis*. Marban and Flores (1993) reported the occurrence of *Pratylenchus coffeae, Helicotylenchus californicum, Aphelenchus* spp., *Tylenchus* spp. and *Scutellonema* spp. with five varieties of *Aglaonema commutatum.* Soomro *et al.* (1993) reported *Amaranthus viridis, Rumex dentatus, Tagetes* sp. and *Zinnia grandiflora* as new host records of *M. incognita* from Islamabad, Pakistan.

Saadabi (1993) in a survey of ornamental plants of Libya revealed the presence of 12 genera and 13 species of plant parasitic nematodes in both the rhizosphere soil and roots. *Meloidogyne incognita, Trichodorus* sp., *Helicotylenchus digonicus, Pratylenchus pratensis, Hoplolaimus egyptiensis* and *Tylenchorhynchus maximus* may become a limiting factor in the growth of ornamental plants if not controlled. Ambrogioni and Derrico (1994) studied the population dynamics of cyst nematode on carnation in campania. They observed that rate of development of nematode was favoured by a temperature

over 24^0C and total nematode number reached the highest level on the roots in September. Mareggiani and Russo (1995) reported the occurrence of 19 genera of nematodes, associated with ornamentals in Buenos Aires and its environs. They observed that *Meloidogyne* spp., *Ditylenchus dipsaci, Aphelenchoides* spp. and *Pratylenchus* spp. were associated with serious decline of ornamental plants.

Petit and Crozzoli (1995) carried out a survey to identify the plant parasitic nematodes associated with ornamental crops in Venezuela. The ornamental plants selected were rose (Rosa sp.), chrysanthemum (*Dendranthema grandiflora*), carnation (*Dianthus* sp.), *Gladiolus* sp., and *Strelitzia reginae,* peruvian lily (*Alstreomeria* sp.) and *Anthurium* sp. The nematodes found in association with these ornamentals were *Criconema, Hemicycliophora, Paratylenchus, Helicotylenchus dihystera, Meloidogyne incognita, Tylenchorhynchus capitatus, Paratylenchus curvitatus,* and *Xiphinema krugi. H. dihystera, M. incognita* and *P. penetrans* were the most numerous and widely distributed nematode pests in the survey.

Jain *et al.* (1996) reported the occurrence of *Helicotylenchus* spp. with some ornamentals in Udaipur region of Rajasthan. *Meloidogyne incognita* is one of the serious

limiting factors in commercial cultivation of carnation and gerbera under polyhouse conditions. Most of the highly fetching exotic cultivars of carnation and gerbera from Europe have shown 40 to 60% mortality in polyhouse beds due to root-knot nematode infection in and around Bangalore (Nagesh and Reddy, 1996). Pathak and Siddiqui (1996) reported new species of *Tylenchorhynchus* i.e. *T. vishwanathensis* associated with jasmine from Udaipur, Rajasthan.

Anitha (1997) reported the presence of *Meloidogyne hapla, Helicotylenchus* sp., *Pratylenchus* sp., *Criconemoides* sp. and *Xiphinema* sp. in geranium root and soil samples collected from Nilgiris area of Tamil Nadu. Khanna and Chandel (1997) pointed out that gladiolus plant inoculated with more than 100 nematodes showed suppression of growth parameters. Khan *et al.* (1997) reported the occurrence of *Tylenchorhynchus annulatus, Helicotylenchus pseudorobustus, H. multicinctus, H. indicus, Pratylenchus brachyurus, P. zeae* and *Hoplolaimus pararobustus* from the rhizosphere of ornamental plants. They also showed that Tenekil 'M' or carbofuran used for their control.

Pathak and Siddiqui (1997) reported new species of *Tylenchorhynchus* i.e *T. crotoni* sp. n. from *Croton* sp. and also reported five known species of *Tylenchorhynchus* viz. *T. ewingi*, *T. mashhoodi, T. punensis, T. brassicae* and *T. leviterminalis* from the rhizosphere of different ornamental crops in Udaipur, Rajasthan.

Pathak *et al.* (1997) reported the occurrence of phytophagous nematodes, associated with soil and roots of woody ornamental plants (*Bougainvillea* sp., *Clerodendron inerme, Hibiscus rosa-sinensis* and *Thuja compacta*) for the first time from Bihar. Pathak and Siddiqui (1997) identified seven spp. of *Tylenchorhynchus* on some ornamentals in Udaipur, India

Chandel *et al.* (1997) in a survey of Solan and Shimla districts of Himachal Pradesh, India for plant parasitic nematodes revealed that *M. incognita* was the most frequently occurring nematode, followed by *Helicotylenchus dihystera* in gladiolus.

Ismail and Amin (1998) reported the association of plant parasitic nematodes with cacti and succulent plants in Egypt. The most widely distributed nematodes were *Ditylenchus, Helicotylenchus, Meloidogyne* and *Tylenchorhynchus* species.

Park *et al.* (1998) reported the occurrence of the *M. hapla* in peony (*Paeonia lactiflora*) fields located in Uisong and Yeongcheon, Korea Republic. The species and cultivars of *Aethionema, Fragaria, Phlox*, *Polygonum, Echinacea, Monarda* and *Patrinia* developed only a few galls produced by the infection of *M. incognita* and *M. arenaria.* Moreover, large number of root galls was developed on species and cultivars of *Achillea, Geranium, Heuchera, Heucherella, Linaria, Nepeta, Nicrembergia, Penstemon* and *Salvia*. There was no difference in the number of root galls caused by *M. arenaria* or *M. incognita* on most plants except for *Penstemon* cultivars. Plant heights and dry weights varied between species and nematode density (Walker and Melin, 1998)

Wilcken and Ferraz (1998) studied the reproduction rates of different *Meloidogyne* spp. and *Pratylenchus* spp. on gladiolus and suggested that most of test cultivars were efficient hosts for *Meloidogyne* spp. Zhang *et al.* (1998) studied the plant parasitic nematodes associated with ornamental plants in Baotou, Inner Mongolia. Their finding revealed the presence of 10 species of nematodes belonging to 6 genera viz. *Helicotylenchus imperialis, H. minzi, H. tumidicaudatus, Meloidogyne arenaria, M. hapla, M. javanica, M. incognita,*

Quinisulcius capitatus, *Rotylenchus laurentinus*, *Longidorus* sp., and *Xiphinema* sp. *Helicotylenchus tumidicaudatus* and *Q. capitatus* were new geographic records for China. Van *et al.* (1999) reported that the plant parasitic nematodes viz. *Pratylenchus penetrans*, *Aphelenchoides* spp. and *Ditylenchus* spp. were associated with ornamental bulbs and cut flowers which causes the losses to these crops. Goyal and Trivedi (1999) evaluated the pathogenicity of *M. incognita* on winter ornamentals (*Antirrhinum majus* and *Dianthus barbatus*) and pointed out that increase in the inoculum level resulted in a progressive increases in host infestation, as indicated by the number of galls as well as nematode multiplication. Latha *et al.* (2000) reported 17 nematode spp. most of which were of economic importance and intercepted form the ornamental plants during 1990-1996. Zeng *et al.* (2000) identified root-knot nematodes from three horticultural plants in China namely *Lantana camara (M. arenaria); Euphorbia cochininchensis (M. javanica and M. incognita);* and *Coleus pumilus (M .incognita).* Johnson *et al.* (2002) revealed that the growth parameters were significantly reduced by the different inoculum levels (10,100, 1000 and 10,000 J_2/ plant) of *M. incognita* in both gladiolus and carnation. It was also observed

that even $100J_2$ / plant could be able to cause economical damage to gladiolus and carnation. A random survey of cut flower growing areas in Nilgiris, Dindigal and Salem districts of Tamil Nadu, India, was conducted to study the occurrence of plant parasitic nematodes associated with gerbera and Asiatic Lily. A total of 8 genera of plant parasitic nematodes were found to be associated with gerbera and 7 with Asiatic Lily. The associated nematodes were *Meloidogyne* spp., *Pratylenchus coffeae, Tylenchorhynchus nanus, Helicotylenchus multicinctus, Xiphinema basiri* and *Longidorus elongatus*. The results also indicated the importance of *M. incognita* and *P. coffeae* in causing major production constraints in gerbera and Asiatic Lily (Johnson *et al.,* 2002).

Aziz *et al.* (2003) conducted studies on the diversity as well as population dynamics of phytoparasitic nematodes associated with some ornamental plants at the campus of Aligarh Muslim University, Aligarh. The nematodes detected in soil samples collected from ornamental plants were *Aphelenchoides sp., Criconemoides* sp., *Helicotylenchus* sp., *Hoplolaimus* sp., *Longidorus* sp., *Meloidogyne* sp., *Pratylenchus* sp., *Tylenchorhynchus* sp., and *Xiphinema* sp. Frequency and diversity of *Hoplolaimus* sp., *Helicotylenchus*

sp., *Criconemoides* sp., and larvae of *Meloidogyne* sp., were quite high. Singh *et al.* (2003) described three new species of *Hemicriconemoides* associated with ornamental plants in Bareilly district of U.P., India.

Sharma and Rich (2005) reported that the landscape plants infected with plant parasitic nematodes particularly root-knot nematodes, *Meloidogyne* spp. showed the stunted growth and can lose aesthetic valve due to chlorosis, wilting and leaf margin necrosis. They also assessed the reproduction of three species of root-knot nematodes viz. *M. arenaria, M. incognita and M. javanica* on five plants (*Hydrangea quercifolia* 'Oakleaf', *Viburnum obovalum* 'Densa', *Ilea-virginica* 'Little Henry', *Illicium parviflorum* and *Clethra alnifolia* 'Ruby Spice' native to the Southeastern U.S.A. and three non-native species *Ligustrum japonicum* 'Texanum', *Ilex crenaia* 'Compacta' and *Buxus microphylla* 'Wintergem'). They noticed that the galling and nematode eggs were abundant on roots of the three non-native taxa. Among the plant species tested, highest galling was observed on roots of *I. crenia* 'Compata' infected with *M. incognita,* but largest no. of eggs was observed in plants of this cultivar inoculated with *M. javanica.* Few or no galls were observed on roots of the five native

plants and nematode eggs were recovered only from roots of *I. virginica* 'Little Henry' inoculated with *M. arenaria* and *M. javanica.* However, weight of shoots or roots of all species was not affected by nematode inoculation. Landscape planting of these plants, therefore, should be recommended as alternatives in sites with soil infested by *M. arenaria, M. incognita* and *M. javanica*.

Khan *et al.* (2006) conducted an experiment to study the pathogenicity and life-cycle of *Meloidogyne javanica* on balsam. They observed that inoculum level of 500 and above J_2/plant significantly decreased the growth parameters. They also reported that the life-cycle of *M. javanica* was completed within 23 days at a temperature ranging between 25-30°C on balsam.

Singh and Tyagi (2007) revealed a number of plant parasitic nematodes associated with sun flower during survey of U.P., Haryana and Punjab States. Out of which reniform nematode, *R. reniformis* was found in greater number. Under field conditions, yellowing, stunting and reduction of sunflower bolls have also been observed. Other nematodes like root-knot, spiral, stunt and lance nematodes were also recorded in the soil samples collected in the three states.

Flower- bulb and ornamental plant growing are high cash value industries. The cost of pest management in ornamental crops isn't a limiting factor as cost benefit ratio permit to adopt any plant protection measure to maintain crop health. Nematode problems in ornamental spread by planting of infested root cutting or bulbs, therefore it must be fully ensured that seed material be clean and free from any pest and pathogens. However, if propagating material is infested with nematodes then it has to be denematised through hot water treatment.

Courtney and Breakey (1945) controlled the infection of *Aphelenchoides fragariae* in *Lilium longifolium* by hot water treatment for 1 h at 43.3°C in Northwest U.S.A. Hot water treatment to chrysanthemum at 46°C for 5 minutes against *A. ritzemabosi* was found quite effective by Stainiland (1950). Criley (1988) denematised the infestations of *A. ritzemabosi* in the rhizome of *Heliconia* spp. by giving hot water treatment at 48°C for 1 h.

Chemical nematicides have been used for the control of plant parasitic nematode in ornamental plants (Olisevich and Protsenko, 1970; Cuany *et al.,* 1974; Jakobsen and Rasmussen, 1976; Crozzoli, 1989; Wojtowiez *et al.,* 1989;

Anyango, 1991), there are some reports where different organic substances have also been used for the management of plant parasitic nematodes (Sayre, 1971; Alam, 1990; Abid *et al.,* 1992; Firoza and Maqbool, 1995). Moreover, combined uses of organic matter with nematicides were more effective in reducing population of plant parasitic nematodes and increased plant growth than either used alone (Bhattacharya and Goswami, 1987, 1988; Abid *et al.,* 1992).

Oostenbrink *et al.* (1957) found that growing *Tagetes* spp. could reduce *Pratylenchus* populations by 90%. Green (1963) confirmed that nematodes in bulb tissue were killed by heat more readily than those in water.

Winotosuatmadji (1967) showed that some ornamental plants of compositae family viz. *Helenium*, *Gaillardia* and *Eriophyllum* suppressed the populations of *Pratylenchus penetrans.* Infection of root-knot nematode was reduced in gladiolus when infected corms were dipped in fensulfothion or nemacur at the rate of 0.5 lb per 100 gal water (Overman, 1970).

Winfield (1972, 1973) suggested the management of *Ditylenchus dipsaci* infecting tulip bulbs by giving hot water treatment and also by spraying of Thionazin in flowers. Dale

(1973) observed that the nemacur @ 0.1% as bare root-dip treatment eliminated the infestation of root-knot nematode (*M. hapla)* in root stocks of dormant budded roses.

Application of granular aldicarb (10% formulation) at the rate of 40 oz per $1000ft^2$ was effective in reducing the *P. penetrans* population in roses (Johnson and McClanaham, 1974). Srinivasan and Muthukrishnan (1976) found that carbofuran (Furadan3G) @ 1 gram per plant effectively reduced the nematode population in crossandra.

Ohkawa and Saigusa (1981) found that *Rosa indica* "Major" and *R. multiflora* were resistant to *Pratylenchus penetrans* and *P. vulnus* respectively. Windrich (1985) investigated the efficacy of aldicarb for the control of *Ditylenchus dipsaci* in tulip at 6kg $a.i.ha^{-1}$ applied to field plots in autumn and spring and oxamyl at 2.88 kg $a.i.\ ha^{-1}$ in spring. Windrich (1986) also investigated the efficacy of aldicarb granules for the control of *D. dipsaci* in narcissus at several rates applied to soil.

Anyango (1988) studied the effect of *M. javanica* and lesion nematodes (*Pratylenchus penetrans)* on pyrethrum seedlings and observed that nemacur (5%) granules

significantly controlled the population of both nematodes in roots and surrounding soil.

Babatola (1988) studied that influence of organic manures and urea on the nematode problems of *Celosia argentea.* They observed that organic manures reduced populations of *Meloidogyne incognita, Pratylenchus* spp. and *Helicotylenchus* spp. after application and similar results were also observed in case of urea.

Landi (1990) tested the strains of entomophilic nematodes, *Heterorhabditis* spp. and *Steinernema* spp. and experimental strains of *Bacillus thuringiensis* subsp. *tenebrionis* and *Verticillium lecanii* for their effectiveness as biological control agents against the *Otiorhynchus suicatus* and *O. saliciola* on ornamental plants and observed that the entomophilic nematodes were more effective against larvae in the soil than the *B. thuringiensis* subsp. *tenebrions,* despite minimum soil temperature being below 12°C, which is considered to be the thermal limits of nematode activity.

Muller *et al.* (1990) reported *Aphelenchoides ritzemabosi* on *Fritillaria imperialis* and *A. ritzemabosi* on *Eremurus stenophyllus*, the latter controlled by hot water treatment.

Anyango (1991) conducted an experiment using two rates of aldicarb, fenamiphos and carbofuran on pyrethrum (*Chrysanthemum cinerarifolium)* clone 4331 which was infested with *M. hapla, P. penetrans* and others plant parasitic nematodes. They observed that at both rates of aldicarb and fenamiphos, nematode populations were significantly reduced, whereas, carbofuran was found effective only when applied at the rate of 3kg/ha a.i. Dunn (1991) reported enthoprophos, fenamiphos and oxamyl for nematode control in ornamental plant nurseries. The use of entomophilic nematodes for the biological control of insect pests during the production of ornamental plants and flowers in Italy is described by Carrai (1992).

Ramakrishnan and Vadivelu (1994) conducted a survey in the chrysanthemum growing areas of Dharmapuri district, Tamil Nadu. They observed the association of *Pratylenchus penetrans, Meloidogyne incognita, Rotylenchulus reniformis* and *Helicotylenchus* spp. with the chrysanthemum. They also revealed that the soil application of carbofuran 3G @ 0.75 kg a.i. /ha is the most effective measure for control of nematodes infecting chrysanthemum.

Chakrabarti (1995) reported that the nuvacron [monocrotrophos] (0.15%) and metacide [parathionmethyl] (0.15%) controlled the disease caused by *Aphelenchoides besseyi* in *Polianthes tuberosa* by 86% and 52% respectively.

The efficacy of *Paecilomyces lilacinus* and *Verticillium chlamydosporium* in the control of *M. incognita* on *Celosia argentea* was tested by Goyal and Trivedi (1998).

Moreover, in mixed cropping system *Tagetes* species (Tiyagi *et al.,* 1985; Bano *et al*., 1986a, b) and *Catharanthus roseus* (Mani *et al.,* 1986; Patel *et al.,* 1987; Rao and Reddy, 1992; Reddy *et al.,* 1993) have shown toxic effects against plant parasitic nematodes.

Materials & Methods

MATERIALS AND METHODS

The different materials to be used and the methods to be employed during the course of proposed experimental programme are generalized as follows:

COLLECTION OF SOIL SAMPLES:

During the course of investigations an extensive survey of A.M.U. campus was carried out for the collection of nematodes associated with ornamental plants. Soil samples (about 1 kg) were taken from the rhizosphere of the plants with the help of trowel or shovel from the depth of about 6-9 inches. Sampling were done randomly from 10-12 different places of an average size field and these sub-samples were mixed together to obtain a composite sample. Roots of the plants were carefully lifted along with the soil samples and placed in a polyethylene bags. Plant and root samples were place in a separate polyethylene bags, sealed tightly and labelled with details of host, locality and date of collection. Samples were stored at 5-10^{0}C until processed for nematode extraction. After the extraction of nematodes, nematodes were identified upto the generic level.

EXTRACTION OF NEMATODES FROM SOIL:

Nematodes were extracted from the soil by using the Cobb's decanting and sieving method followed by Baermann funnel techniques (Southey, 1986). From each polythene bags about 250g soil sample was put in a large bucket containing water and stirred until the lumps were broken and stones removed. Suspension was allowed to settle for about two minutes. The heavy particles sank to the bottom and nematode remained suspended in water. The suspension was slowly poured through a 25 mesh sieve to another bucket. More water was added to the bucket 'A' and the above process was repeated. The residue left over the 25 mesh sieve was discarded and the filtrate so obtained was then passed through 400 or 500 mesh sieves. The residue left over 400/500 mesh sieve was collected in a 250ml beaker with the help of wash bottle.

The suspension thus obtained from 400/500 mesh sieve was poured into a double layered tissue paper mounted over a coarse sieve placed over a 10 cm diameter funnel provided with a rubber tube clipped with a stop cock containing as much water as that touches only the brim of the sieve. After 24

hours, the suspension of nematode drained out through the rubber tube into a beaker and then examined for nematode species under stereoscopic microscope.

EXTRACTION OF NEMATODES FROM ROOTS:

The roots were carefully and gently washed to clean the adhering soil particles and then examined under stereoscopic microscope to identify nematodes parasitizing the roots of ornamental plants. For the extraction of nematodes from the roots, the roots were washed and cut into small pieces of about 1-2 cms and then macerated in an electrically operated waring blender containing 100ml water. The blender was operated for 10-20 seconds and the macerate thus obtained was collected in a beaker. Later on, it was filtered through a 25 mesh sieve and the filterate was examined for nematodes under the stereomicroscope.

QUANTITATIVE ANALYSIS:

For quantitative analysis, 5 ml nematode suspension was poured in a counting dish and the nematodes were counted under a stereomicroscope. At least three readings were taken to calculate the average number of nematodes in 100 ml of

suspension. The nematode population per 100 gm of soil was thus determined.

QUALITATIVE ANALYSIS:

For qualitative analysis, the nematode suspension was allowed to settle for some time. The excess supernatent was poured off, the remaining concentrated contents were transferred into a cavity block for examination under a stereomicroscope.

KILLING AND FIXING:

The nematode suspension in a beaker of 50 ml capacity was left undisturbed for about 1-2 h enabling the nematodes to settle down to the bottom. The excess water was then carefully decanted so that the nematodes are left in a minimum quantity of water.

Double strength TAF- approximately the equal quantity of nematode suspension was heated in a test tube over a water bath till water droplet appears in the test tube. This heated TAF was then added to the nematode suspension which killed and fixed the nematodes immediately. This suspension was stored in a glass or plastic vial for further processing.

STAINING OF NEMATODE:

Roots were washed to free from soil and other adhering debris and cut into small pieces. Plunge the material into boiling lactophenol containing 0.1 percent cotton blue stain and continue boiling for 2-5 minutes. Remove the root pieces and wash off excess stain in running water, place it in a Petridish containing plain lactophenol. Allow tissues to differentiate for several hours to two or three days. Examine them in lactophenol under a stereomicroscope; nematodes were stained in blue colour, whereas, plant tissue remains largely unstained.

Liquid Phenol	:	50 ml
Lactic Acid	:	50 ml
Glycerine	:	100 ml
Distilled water	:	50 ml

PERMANENT MOUNTING:

Already killed and fixed nematodes were transferred to a small amount of plain lactophenol in a cavity block. The cavity block was then transferred to an incubator for 5 minutes at 55^0C after which a drop of dehydrated glycerine was added to it. Similarly, after another 5 minutes a drop of glycerine was

added and the cavity block was taken out from the incubator. In this way the constituents of lactophenol was evaporated and the nematode was left in pure glycerine. The cavity block was transferred to a desiccatar till processing for mounting.

For mounting, a small droplet of dehydrated glycerine was put on the centre of glass slide. Four or five specimens of the same nematode species, was transferred to the droplet with the help of brush. Three small pieces of glass wool fibres was placed radially and peripherally in the glycerine drop before placing a cover slip over the nematode. Before the coverslip was lowered over the nematode, it was cleaned, gently moved over the flame and then a droplet of dehydrated glycerine was added to it. This avoids the air bubbles to remain in the glycerine drop within the coverslip. The edges of the coverslip was then sealed with glyceel.

PREPARATION AND STERILIZATION OF SOIL MIXTURE:

Soil collected from the field near to A.M.U. campus was sieved through 16 mesh sieve to remove stone particles. This soil was mixed with sand and organic manure in the ratio of 3:1:1 respectively. Throughout the course of studies, 6 inch pots were filled with this soil mixture at the rate of 1 kg/pot. A

little amount of water was poured in each pot to wet the soil before transferring to an autoclave for sterilization at 20 lb pressure for 20 minutes. Sterilized pots were allowed to cool at the room temperature before use for experiments.

RAISING AND MAINTENANCE OF TEST PLANTS:

Seeds of cock'scomb (*Celosia cristata*) and coleus (*Coleus blumei*) plants were surface sterilized with 0.1% mercuric chloride ($HgCl_2$) for 2 minutes and washed thrice in sterilized water. Seeds were sown in 15″ earthern pots for raising the seedlings. The seedlings of false eranthemum (*Pseuderanthemum atropurpureum*) were raised through stem cuttings of uniform size. Before planting, the cuttings were sterilized with mercuric chloride as mentioned above and then these cuttings were planted in 15″ earthern pots containing 2 kg sterilized soil. The plants were irrigated with water as and whenever required.

RAISING AND MAINTENANCE OF PURE CULTURES OF NEMATODES:

Separate pure culture of *Meloidogyne incognita, Rotylenchulus reniformis* and *Helicotylenchus dihystera* were raised on brinjal, castor and celosia plants, respectively. For raising the culture of *M. incognita* and *R. reniformis*, a single

eggmass was collected from the roots of brinjal and castor plants respectively. The eggmass was surface sterilized by treating it with 1:500 aqueous solution of chlorox (calcium hypochlorite) for 5 minutes. Treated eggmass was washed thrice in distilled water. The eggs in the eggmass were allowed to hatch out separately at 27^0C under aseptic conditions on a sieve layered with tissue paper and kept in a Petridish containing sufficient amount of sterilized distilled water. For raising the culture of *H. dihystera,* about 100 gravid females of this nematode were picked up from the nematode suspension. Brinjal, castor and celosia seedlings grown in 12″ clay pots containing autoclaved soil was inoculated with the second stage juveniles (J_2) of *M. incognita,* immature females of *R. reniformis* and gravid females of *H. dihystera* respectively. Species of these nematodes were extracted from the soil of the pots after a month of inoculation through sieves of 16, 60, and 400 mesh according to Cobb's decanting and sieving method followed by Baermann funnel technique (Southey, 1986).The respective nematodes so obtained were used for inoculating fresh seedlings of brinjal, castor and celosia growing in several clay pots (12″ in size) containing sterilized soil. Root-knot, reniform and spiral nematodes infested the

roots and multiplied there on in the respective hosts. After 6-8 weeks, a little of soil from near the root zone and roots of inoculated plants was examined separately to confirm the establishment and multiplication of each nematode species. After 2-3 months, the plants were cut at the ground level and soil was processed for nematode extraction. The roots were washed thoroughly under running tap water, cut into small pieces and transferred near the root zone of brinjal, castor and celosia seedlings growing in earthen pots. Separate soil suspension containing *M. incognita, R. reniformis* and *H. dihystera* were also transferred, with the help of sterilized pipette to the root zone. These nematodes were inoculated on respective hosts from time to time in order to maintain regular supply of inoculum.

PREPARATION OF NEMATODE INOCULUM:

After 2-3 months, several eggmasses of root-knot nematode (*M. incognita*) were handpicked with the help of forcep from heavily infected roots of brinjal plants. These eggmasses were washed in distilled water and placed in a sieve containing crossed layer of double tissue paper. The sieve was placed over Petridish (10cm in diameter) containing

water. The water level was kept in such a way that it just touches the lower portion of the sieve having eggmasses. After every 24 hours, the hatched out larvae were collected along with water from Petridishes in a beaker and fresh water added to the Petridishes. A series of such assemblies were kept to obtain the inocula of root-knot nematode required for inoculation. Similarly, for the preparation of inocula of *R. reniformis* and *H. dihystera*, the soil was collected from the root zone of heavily infected castor and celosia plants respectively. The soil collected from these plants were separately processed for the extraction of reniform and spiral nematodes by using the technique Cobb's decanting and sieving method as described earlier.

Separate water suspension of above mentioned nematodes were thoroughly stirred for making homogenous distribution of nematodes before taking 10ml suspension in the counting dish for counting the number of nematodes from each sample under the stereoscopic microscope. An average of five counts was taken to determine the density of nematode in the suspension.

Volume of water in the nematode suspension was so adjusted that each ml contained about 100 nematodes. It was

done by adding more water or decanting the excess amount of water, so that 10 ml of this suspension provide 1000 nematodes.

INOCULATION TECHNIQUE:

Two week old seedlings of *C. blumei* and *C. cristata* and three week old seedlings of *P. atropurpureum* were inoculated with *R. reniformis*, *H. dihystera* and *M. incognita* respectively. Feeder roots of seedlings were exposed just before inoculation, removing the top layer of soil and required quantity of nematode suspension inoculum were transferred with the help of sterilized pipette. Immediately after inoculation, the exposed roots were covered by levelling the soil properly. Throughout these studies each treatment was replicated three times and uninoculated plants served as control. Regular watering was done to maintain the soil moisture. Experiments were terminated after 60 days of inoculation.

EXPERIMENTS:

SURVEY OF PLANT PARASITIC NEMATODES ASSOCIATED WITH ORNAMENTAL PLANTS:

During the course of investigations an extensive survey of A.M.U. campus was carried out for the collection of nematodes associated with ornamental plants. Soil samples

(about 1 Kg) were taken from the rhizosphere of the plants with the help of trowel or shovel from the depth of about 6-9 inches. The nematodes were isolated from these samples by using Cobb's decanting and sieving method followed by Baermann funnel technique. After the extraction of nematodes, nematodes were identified upto generic level. Absolute frequency, relative frequency, absolute density relative density and prominence value of each nematode genus were determined as follows (Norton, 1978).

$$\textbf{Absolute frequency} = \left(\frac{\text{number of samples containing a species}}{\text{total no. of samples collected}}\right) X100$$

$$\textbf{Relative frequency} = \left(\frac{\text{Frequency of species}}{\text{sum of frequency of all species}}\right) X100$$

$$\textbf{Absolute density} = \left(\frac{\text{number of individuals of a species in a sample}}{\text{volume of sample}}\right) X100$$

$$\textbf{Relative density} = \left(\frac{\text{number of individuals of a species in a sample}}{\text{total of all individuals in a sample}}\right) X100$$

$$\textbf{Prominence value} = \text{Absolute density} \sqrt{\text{Absolute frequency}}$$

OCCURRENCE OF ROOT-KNOT AND RENIFORM NEMATODES IN ORNAMENTAL PLANTS GROWN IN A.M.U. CAMPUS:

An extensive survey of about 50 ornamental plants grown in A.M.U. campus were carried out to find out the infection of root-knot nematodes (*Meloidogyne* spp.) and

reniform nematode (*Rotylenchulus reniformis)*. Twenty five plants of each ornamental species were collected to observed for the infection of *Meloidogyne* spp. and *Rotylenchulus reniformis* in the roots. The species of *Meloidogyne* were identified on the basis of perineal pattern morphology as proposed by the Hartman and Sasser (1985). The percentage infection of root-knot nematodes and average no. of galls/root system of ornamental plant were calculated. Similarly, the percentage of infection of reniform nematodes and no. of females/ root system of ornamental plant were also calculated.

STUDIES ON THE PATHOGENICITY OF PLANT PARASITIC NEMATODES ASSOCIATED WITH ORNAMENTAL PLANTS:

The studies were conducted to determine the inoculum threshold level of root-knot nematode (*M. incognita)*, reniform nematode (*R. reniformis)* and spiral nematode *(H. dihystera)* on *Pseuderanthemum atropurpureum, Coleus blumei* and *Celosia cristata* respectively. Three week old seedlings of *P. atropurpureum* and two week old seedling of *C. blumei* and *C. cristata* were inoculated with different inoculum levels viz. 500, 1000, 2000, 4000 and 8000 of *M. incognita* (2nd stage juveniles), *R. reniformis* (immature females) and *H. dihystera*

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(gravid females) excluding males in case of reniform and spiral nematodes.

RECORDING OF OBSERVATIONS:

PLANT GROWTH DETERMINATION:

The plants were uprooted after 60 days of inoculation and their roots were gently washed off the soil, taking utmost care to avoid losses and injury to roots during the entire operation. For measuring length and dry weight, the plants were cut with a sharp knife just above the base of root emergence. The length of the shoots and roots was recorded in centimeters from the cut end to the top of first leaf and the longest root respectively. The weight was recorded in grams. For dry weight, the roots and shoots were kept in envelopes for drying in an oven running at 60°C for 2-3 days. Reduction in dry weight of plants (root +shoot) was calculated in terms of percentage dry weight reduction.

ROOT-KNOT ESTIMATION:

The galling caused by root-knot nematode was estimated by counting the number of galls per root system.

NEMATODE POPULATION ESTIMATION:

For extraction of nematodes, the soil from the pots of each treatment was mixed thoroughly and a sub-sample of

200gm soil was processed through sieves according to Cobb's decanting and sieving method followed by Baermann funnel technique. The nematode suspension was collected in a beaker and volume made upto 100ml. For proper distribution of nematodes, the suspension was bubbled with the help of pipette and 2ml suspension from each sample was drawn and transferred to a counting dish. The numbers of nematodes were counted in five replicates for each sample. Mean of the five such counting's was calculated and the final population of nematodes/kg soil was also calculated.

Reproduction factor (R) of each nematode species was calculated by the formula $R=P_f/P_i$ where 'P_f' represents the final and 'P_i' represents initial population of the nematode.

STATISTICAL ANALYSIS:

The data obtained were analyzed statistically and significance of variance was calculated at P=0.05 and P=0.01 levels of probability.

Results

RESULTS

SURVEY OF THE PLANT PARASITIC NEMATODES ASSOCIATED WITH ORNAMENTAL PLANTS IN A.M.U. CAMPUS

The results on the survey of plant parasitic nematodes associated with ornamental plants carried out in different localities of A.M.U. campus are presented in Tables-1.1 to 1.3. Total nine genera of plant parasitic nematodes viz. *Aphelenchoides* sp., *Helicotylenchus* sp., *Hoplolaimus* sp., *Meloidogyne* sp., *Pratylenchus* sp., *Rotylenchulus* sp., *Tylenchorhynchus* sp., *Tylenchus* sp. and *Xiphinema* sp. were found in 144 soil samples collected from the rhizosphere of ornamental plants (Table-1.1). Among the nematodes isolated, root-knot nematodes were found in high frequency and widely distributed.

It was recorded that the root-knot nematode, *Meloidogyne* sp. has higher densities in the field having ornamental plants, i.e. *Althea rosea* (150/200 cm^3 soil), *Dahlia variabilis* (106/200 cm^3 soil), *Dianthus caryophyllus* (103/200 cm^3 soil), *Phlox drummondii* (100/200 cm^3 soil), *Celosia cristata* (103/200 cm^3 soil), *Rosa indica* (140/200 cm^3 soil), *Coleus blumei* (102/200 cm^3 soil), *Jasminum sambac* (122/200

cm^3 soil), and *Impatiens balsamina* (100/200 cm^3 soil). Highest density of reniform nematode, *Rotylenchulus* was observed in *Chrysanthemum indicum* (53/200 cm^3 soil), and lowest in case of *Salvia splendens* and *Mirabilis jalapa* (12/200 cm^3 soil). The spiral nematode, *Helicotylenchus* was found in highest number in field having *Althea rosea* (119/200 cm^3 soil), whereas, its lowest density was recorded in *Tagetes erecta* (20/200 cm^3 soil). The highest density of stunt nematode, *Tylenchorhynchus* was found in *Plumeria alba* (90/200 cm^3 soil) and lowest density was recorded in *Celosia cristata* and *Salvia splendens* (10/200 cm^3 soil). The maximum density of lance nematode, *Hoplolaimus* was recorded in *Althea rosea* (72/200 cm^3 soil), and minimum density was present in *Coleus blumei* (15/200 cm^3 soil). However, it was absent in field having *Hibiscus rosa-sinensis. Tylenchus* and *Xiphinema* were found in highest number (84/200 cm^3 soil and 40/200 cm^3 soil) in *Althea rosea.* The density of *Pratylenchus* was highest (40/200 cm^3 soil) in *Iberis amara* and *Jasminum sambac.* Moreover, *Pratylenchus* was absent in *P. hybrida, C. cristata, P. alba, C. officinalis* and *S. splendens.* The maximum density of *Aphelenchoides* (44/200 cm^3 soil), was recorded in *Althea rosea* and minimum (4/200 cm^3 soil), in *Tagetes erecta.*

Table- 1.1: Occurrence of plant parasitic nematodes in ornamental plants in A.M.U. campus.

Ornamental plants	No. of soil samples	Nematodes* associated with ornamental plants									
		Aph.	Hel.	Hop.	Mel.	Prat.	Roty.	Tyle.	Tyl.	Xip.	Sap.
Althea rosea	8	4	6	6	7	2	4	2	5	3	8
Calendula officinalis	8	-	6	8	7	-	4	3	2	-	5
Celosia cristata	8	1	8	6	5	-	4	2	3	2	5
Chrysanthemum indicum	8	4	4	6	5	4	5	5	3	1	5
Coleus blumei	8	2	4	3	4	2	5	1	-	-	5
Dahlia variabilis	8	-	5	4	8	3	6	5	2	2	6
Dianthus caryophyllus	8	2	5	4	8	3	-	5	2	1	6
Hibiscus rosa-sinensis	8	4	4	-	6	4	5	2	4	3	5
Iberis amara	8	-	4	6	7	5	4	2	1	3	4
Impatiens balsamina	8	3	5	3	7	6	2	-	3	2	4
Jasminum sambac	8	2	4	3	4	5	4	2	4	2	3
Mirabilis jalapa	8	2	3	4	6	1	2	2	4	2	4
Petunia hybrida	8	-	5	4	5	-	4	-	1	-	5
Phlox drummondii	8	-	7	3	6	3	3	3	2	2	7
Plumeria alba	8	2	7	4	5	-	4	6	3	-	5
Rosa indica	8	-	4	5	6	5	4	-	2	4	6
Salvia splendens	8	4	1	3	5	-	1	1	-	-	4
Tagetes erecta	8	1	5	4	5	1	4	2	3	3	4
Total no. of samples	**144**	**31**	**87**	**76**	**106**	**44**	**65**	**43**	**44**	**30**	**91**

* Aph.= *Aphelenchoides*, Hel. = *Helicotylenchus*, Hop. = *Hoplolaimus*, Prat.= *Pratylenchus*, Roty.= *Rotylenchulus*, Tyle.= *Tylenchorhynchus*, Tyl.= *Tylenchus*, Xip.= *Xiphinema* Sap.= Saprozoic.

Table- 1.2: Nematodes (per 200 cm^3 soil) associated with ornamental plants in A.M.U. campus.

Ornamental plants	Nematodes									
	Aph.	Hel.	Hop.	Mel.	Prat.	Roty.	Tyle.	Tyl.	Xip.	Sap.
Althea rosea	44	119	72	150	16	40	18	84	40	103
Calendula officinalis	-	24	48	100	-	16	21	12	-	20
Celosia cristata	6	48	18	103	-	24	10	18	12	20
Chrysanthemum indicum	43	37	70	78	28	53	37	18	12	28
Coleus blumei	10	24	15	102	24	45	18	-	-	55
Dahlia variabilis	-	50	22	106	32	46	50	9	21	65
Dianthus caryophyllus	18	62	50	103	25	-	15	6	9	62
Hibiscus rosa-sinensis	20	24	-	62	12	30	14	16	18	25
Iberis amara	-	28	53	75	40	25	15	6	22	25
Impatiens balsamina	21	40	24	100	36	14	-	27	10	24
Jasminum sambac	12	40	21	122	40	24	12	20	12	21
Mirabilis jalapa	20	33	24	106	16	12	14	32	6	40
Petunia hybrida	-	62	47	43	-	50	-	6	-	68
Phlox drummondii	-	65	16	100	16	29	25	44	22	48
Plumeria alba	12	72	43	92	-	16	90	28	-	78
Rosa indica	-	44	25	140	15	24	-	8	12	36
Salvia splendens	32	31	30	45	-	12	10	-	-	24
Tagetes erecta	4	20	16	25	12	44	12	18	24	32
Total	**242**	**823**	**594**	**1652**	**312**	**504**	**361**	**352**	**220**	**774**

Table- 1.3: Community analysis of plant parasitic nematodes associated with some ornamental plants in A.M.U. campus.

Nematodes	Average No./200 cm^3 soil	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
Aphelenchoides	13	21.53	5.02	6.5	4.1	29.9
Helicotylenchus	45	60.42	14.10	22.5	14.1	173.2
Hoplolaimus	33	52.78	12.32	16.5	10.3	118.8
Meloidogyne	91	73.61	17.18	45.5	28.3	386.7
Pratylenchus	17	30.56	7.13	8.5	5.3	46.7
Rotylenchulus	28	45.13	10.53	14.0	8.7	93.8
Tylenchorhynchus	20	29.86	6.96	10.0	6.2	54.0
Tylenchus	19	30.55	7.13	9.5	5.9	52.2
Xiphinema	12	20.83	4.86	6.0	3.7	27.0
Saprozoic	43	63.19	14.75	21.5	13.4	169.8

Maximum prominence value was recorded in case of *Meloidogyne* sp. (386.7) followed by *Helicotylenchus* sp. (173.2), *Hoplolaimus* sp. (118.8), *Rotylenchulus* sp. (93.8), *Tylenchorhynchus* sp. (54.0), *Tylenchus* sp. (52.2), *Pratylenchus* sp. (46.7), *Aphelenchoides* sp. (29.9) and *Xiphinema* sp. (27.0) (Table-1.3). Thus, the root-knot nematode emerged as an important nematode in the region where ornamental plants are grown. Most of the ornamental plants growing in the area, infested with plant parasitic nematodes showed symptoms of yellowing of foliage, stunting of plant growth, unthrifty growth and root galls in the root system of the plants infected with *Meloidogyne* sp.

Besides plant parasitic nematodes, some saprozoic nematodes were also found associated with the ornamental plants. Saprozoic nematodes were found in higher number (103/200 cm^3 soil) in *A. rosea* and lower (21/200 cm^3 soil) in *J. sambac.* Prominence value of saprozoic nematodes were recorded as 169.8.

OCCURRENCE OF ROOT-KNOT AND RENIFORM NEMATODES IN ORNAMENTAL PLANTS GROWN IN AMU CAMPUS

It is evident from the data presented in Table-2.1 that reniform nematode (*Rotylenchulus reniformis*) and three

species of root-knot nematodes viz. *Meloidogyne incognita, M. javanica* and *M. arenaria* were found to be associated with different ornamental plants grown in A.M.U. campus. Out of 50 species of ornamental plants studied, 29 species of ornamental plants were found to be infected with root-knot nematodes (*Meloidogyne* spp.).The highest percentage of infection of root-knot nematodes (*Meloidogyne* spp.) was observed in *Impatiens balsamina* (100.0) followed by *Celosia cristata* (97.0), *Mirabilis jalapa* (96.0), *Acalypha wilkesiana* (88.0), *Pseuderanthemum atropurpureum* (80.0), *Althea rosea* (76.0) , *Rosa indica* (73.0), *Jasminum sambac* (72.0), *Canna indica* (71.0), *Coleus blumei* (68.0), *Calendula officinalis* (65.0), *Kochia scoparia* (64.0), *Amaranthus caudatus* (60.0), *Bougainvillea spectabilis* (58.0), *Callistemon lanceolatus* (49.0), *Petunia hybrida* (49.0), *Antirrhinum majus* (48.0), *Bryophyllum pinnatum* (46.0), *Helianthus annus* (44.0), *Dahlia variabilis* (41.00), *Dianthus caryophyllus* (41.0), *Hibiscus rosa-sinensis* (40.0), *Phlox drummondii* (36.0), *Chrysanthemum indicum* (32.0), *Delphinium ajacis (*25.0), *Tropaeolium majus* (24.0), *Plumeria alba* (16.0) and *Cosmos bippinatus* (14.0).

Out of 29 plants infected with *Meloidogyne* spp., 27 plants were infected with *M. incognita* followed by 20 and 9

plants were infected with *M. javanica* and *M. arenaria* respectively. Among the *Meloidogyne* spp., the highest percentage of infection of *M. incognita* was observed in *Pseuderanthemum atropurpureum* (80.0) and lowest percentage of infection of *M. incognita* was observed in *Dianthus caryophyllus* (5.0), whereas, highest percentage of infection of *M. javanica* and *M. arenaria* was observed in *Mirabilis jalapa* (72.0), and *Celosia cristata* (28.0) and lowest in *Phlox drummondii* (7.0) and *Althea rosea* (6.0), respectively.

The maximum number of galls produced by *M. incognita, M. javanica* and *M. arenaria* were observed in *P.atropurpureum* (102.4), *I. balsamina* (70.2) and *C. cristata* (37.0), respectively, whereas, the minimum number of galls caused by *M. incognita, M. javanica* and *M. arenaria* were observed in *J. sambac* (20.0), *P. drummondii* (18.2) and *A. caudatus* (12.0). Mostly there was a direct correlation between the degree of infection and the formation of galls by *Meloidogyne* spp. in ornamental plants. However, in some cases the direct correlation was not found as the reduced numbers of galls were recorded in those ornamentals showing higher infection in the field.

In case of *Rotylenchulus reniformis,* only 15 species of ornamental plants were found to be infected with the reniform nematode. The highest percentage of infection of reniform nematode, (*R. reniformis*) was observed in *Hibiscus rosa-sinensis* (56.0) followed by *Petunia hybrida* (55.0), *Impatiens balsamina* (52.0), *Dahlia variabilis* (44.0), *Kochia scoparia* (42.0), *Thevetia peruviana* (40. 0), *Coleus blumei* (32.0), *Dianthus caryophyllus* (29.0), *Jasminum sambac* (28.0), *Plumeria alba* (26.0), *Chrysanthemum indicum* (24.0), *Rosa indica* (22.0), *Helianthus annus* (21.0), *Calendula officinalis* (12.0) and *Althea rosea* (8.0). Moreover, the highest number of females of reniform nematodes per root system was recorded in *D. variabilis* (62) followed by *P. hybrida* (60), *H. rosa-sinensis* (51), *I. balsamina* (48), *T. peruviana* (46), *C. blumei* (45), *D. caryophyllus (*40), *K. scoparia* (33), *R. indica* (32), *J. sambac* (30), *C. officinalis* (27), *P. alba* (25), *H. annus* (24), *C. indicum* (23) and *A. rosea* (22).

It can be concluded from the above result that there was a direct correlation between degree of infection and the number of females per root system in ornamental plants except in case of *Hibiscus rosa-sinensis* and *Kochia scoparia.*

Table- 2.1: Occurrence of root-knot and reniform nematodes in ornamental plants grown in A.M.U. campus.

Ornamental plants	Families	Percentage of plant infected with *Meloidogyne* spp.			Total	Percentage of plant infected with *Rotylenchulus reniformis*	No. of females per root system
		M. incognita	*M. javanica*	*M. arenaria*			
Acalypha wilkesiana L.	Euphorbiaceae	64.0(78.4)	24.0(40.0)	-	88.0	-	-
Althea rosea L.	Malvaceae	56.0(32.0)	14.0(68.0)	6.0(18.2)	76.0	8.0	22
Amaranthus caudatus L.	Amaranthaceae	24.0(23.0)	20.0(29.0)	16.0(12.0)	60.0	-	-
Antirrhinum majus L.	Scrophulariaceae	32.0(42.2)	16.0(20.1)	-	48.0	-	-
Bougainvillea spectabilis wild.	Nyctaginaceae	34.0(64.2)	24.0(32.4)	-	58.0	-	-
Bryophyllum pinnatum Lam.	Crassulaceae	10.0(21.2)	36.0(57.0)	-	46.0	-	-
Calendula officinalis L.	Asteraceae	48.0(36.0)	17.0(24.2)	-	65.0	12.0	27
Callistemon lanceolatus DC.	Myrtaceae	49.0(32.2)	-	-	49.0	-	-
Canna indica L.	Cannaceae	51.0(42.0)	20.0(34.0)	-	71.0	-	-
Celosia cristata L.	Amaranthaceae	45.0(50.0)	24.0(22.0)	28.0(37.0)	97.0	-	-
Chrysanthemum indicum L.	Asteraceae	32.0(26.2)	-	-	32.0	24.0	23
Coleus blumei Benth.	Lamiaceae	68.0(64.0)	-	-	68.0	32.0	45
Cosmos bippinatus Cav.	Asteraceae	-	14.0(24.9)	-	14.0	-	-
Dahlia variabilis Desf.	Asteraceae	41.0(40.2)	-	-	41.0	44.0	62
Delphinium ajacis L.	Ranunculaceae	-	-	25.0(33.0)	25.0	-	--

Cont.....

Dianthus caryophyllus L.	Caryophyllaceae	5.0(25.0)	9.0(24.2)	27.0(22.0)	41.0	29.0	40
Helianthus annus L.	Asteraceae	12.0(32.2)	24.0(20.0)	8.0(24.4)	44.0	21.0	24
Hibiscus rosa-sinensis L.	Malvaceae	16.0(44.4)	17.0(26.0)	7.0(13.3)	40.0	56.0	51
Iberis amara L.	Cruciferae	20.0(26.2)	-	-	20.0	-	--
Impatiens balsamina L.	Balsaminaceae	48.0(92.0)	32.0(70.2)	20.0(30.0)	100.0	52.0	48
Jasminum sambac L.	Oleaceae	16.0 (20.2)	56.0(44.0)	-	72.0	28.0	30
Kochia scoparia (L.) Roth.	Chenopodiaceae	40.0(84.2)	24.0(52.0)	-	64.0	42.0	33
Mirabilis jalapa L.	Nyctaginaceae	24.0(62.2)	72.0(40.0	-	96.0	-	-
Petunia hybrida Hort.	Solanaceae	32.0(26.2)	17.0(20.0)	-	49.0	55.0	60
Phlox drummondii Hook.	Polemoniaceae	17.0(22.0)	7.0(18.2)	12.0(21.2)	36.0	-	-
Plumeria alba Tourn.	Apocynaceae	16.0(32.0)	-	-	16.0	26.0	25
Pseuderanthemum atropurpureum L.	Acanthaceae	80.0(102.4)	-	-	80.0	-	-
Rosa indica L.	Rosaceae	40.0(32.2)	33.0(26.0)	-	73.0	22.0	32
Thevetia peruviana K. Schum.	Apocynaceae	-	-	-	-	40.0	46
Tropaeolium majus L.	Tropaeolaceae	24.0(32.0)	-	-	24.0	-	-

In parenthesis are given number of galls /root system.

STUDIES ON THE PATHOGENICITY OF *MELOIDOGYNE INCOGNITA* ON *PSEUDERANTHEMUM ATROPURPUREUM*

It is evident from the data presented in Tables-3.1 and 3.2, Fig.1 and 1.1 that the plant growth reduction of *Pseuderanthemum atropurpureum* was directly proportional to the inoculum levels of *M. incognita*/plants. The inoculation of plants with 500, 1000, 2000, 4000 and 8000 J_2 / plant resulted in 3.0, 24.0, 28.8, 32.1 and 34.7% reduction in plant growth, respectively as compared to control. Although, the significant reduction in plant growth was recorded at and above inoculum level of 1000 J_2 / plant. The plant growth was not significant between the inoculum levels of 2000 and 4000 J_2 and 4000 and 8000 J_2 / plant.

A significant linear relationship was found between the initial population 'Pi' and the final population 'P_f' of *M. incognita.* The multiplication of root-knot nematode significantly reduced with the increase in the inoculum levels. The reproduction factor was highest (12.78) at minimum inoculum level (500 J_2 / plant) and lowest (2.2 3) at the maximum inoculum level (8000 J_2 / plant). Thus, the rate of nematode multiplication showed a declining trend with the increase in the initial inoculum levels suggesting it to be a

density dependent phenomenon. Similarly, there was a significant increase in the number of galls per root system with increase in the inoculum levels. The number of galls per root system was recorded as 46, 105, 140, 159 and 172 at the inoculum levels of 500, 1000, 2000, 4000 and 8000 J_2 / plant, respectively. It can be concluded from these results that the damaging threshold levels of *M. incognita* was found as 1000 J_2 / plant.

The *P. atropurpureum* infected with *M. incognita* were dwarfed, yellowish with smaller foliage and overall showing poor growth of the plant. These symptoms are often mistaken for macro or micronutrient deficiency or moisture stress. The plants inoculated with 4000 and 8000 J_2 / kg soil showing the day time temporary wilting. The below ground symptoms on the roots are small galls, which in case of multiple infection on the nearby tissue may coalesce to form large galls. Besides galling some pimple like tubercles at the base of stem near to the soil level were also found. It is interesting to note that the severity of the above symptoms increase with the increase in the inoculum levels.

Table-3.1: Studies on the pathogenicity of *Meloidogyne incognita* on *Pseuderanthemum atropurpureum.*

Inoculum levels	Plant length (cm)			Plant fresh weight (g)			Plant dry weight (g)			Percentage reduction over control	No. of galls per root system
	Shoot	Root	Total	Shoot	Root	Total	Shoot	Root	Total		
0	42.6	24.2	66.8	90.5	48.2	138.7	30.1	16.0	46.1	-	0
500	41.5	22.9	64.4	89.0	47.3	136.3	29.9	14.8	44.7	3.0	46
1000	32.1	17.5	49.6	72.8	38.5	111.3	23.3	11.7	35.0	24.0	105
2000	30.7	17.1	47.8	70.3	36.9	107.2	21.9	10.9	32.8	28.8	140
4000	29.6	16.4	46.0	66.4	35.3	101.7	21.0	10.3	31.3	32.1	159
8000	28.8	15.7	44.5	64.8	34.3	99.1	20.2	9.9	30.1	34.7	172
C.D (P=0.05)			3.92			6.10			3.37		9.57
C.D. (P=0.01)			5.94			9.23			5.11		15.00

Table-3.2: Effect of different inoculum levels on the multiplication of *Meloidogyne incognita* in *Pseuderanthemum atropurpureum*.

Inoculum levels	Nematode population per pot			Reproduction factor (R=Pf/Pi)
	Juveniles	Females	Total	
500	6107	283	6390	12.78
1000	9423	410	9833	9.83
2000	12513	467	12980	6.49
4000	16546	519	17065	4.26
8000	17292	588	17880	2.23
C.D (P=0.05)				1.54
C.D (P=0.01)				1.93

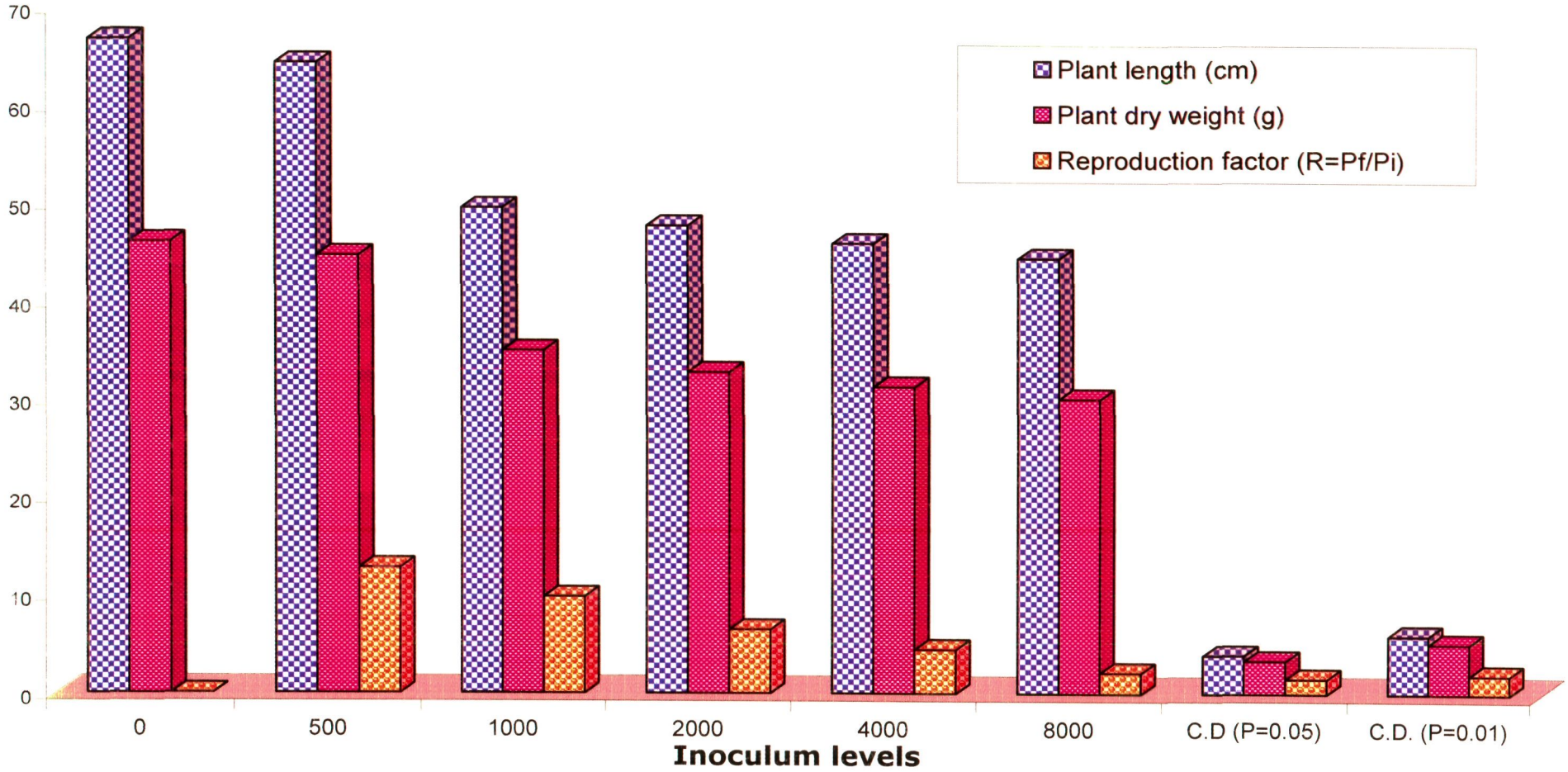
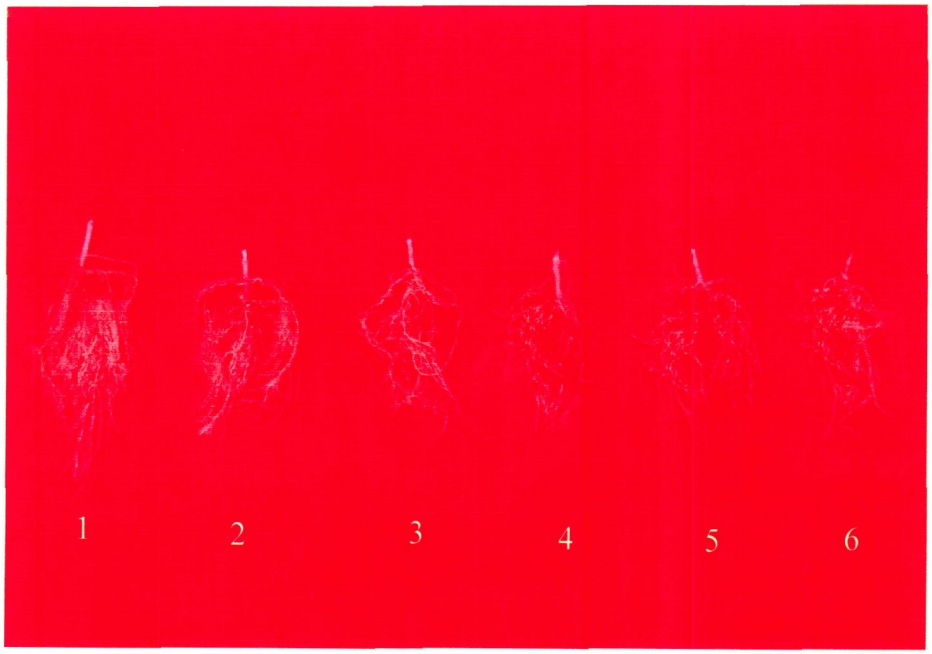
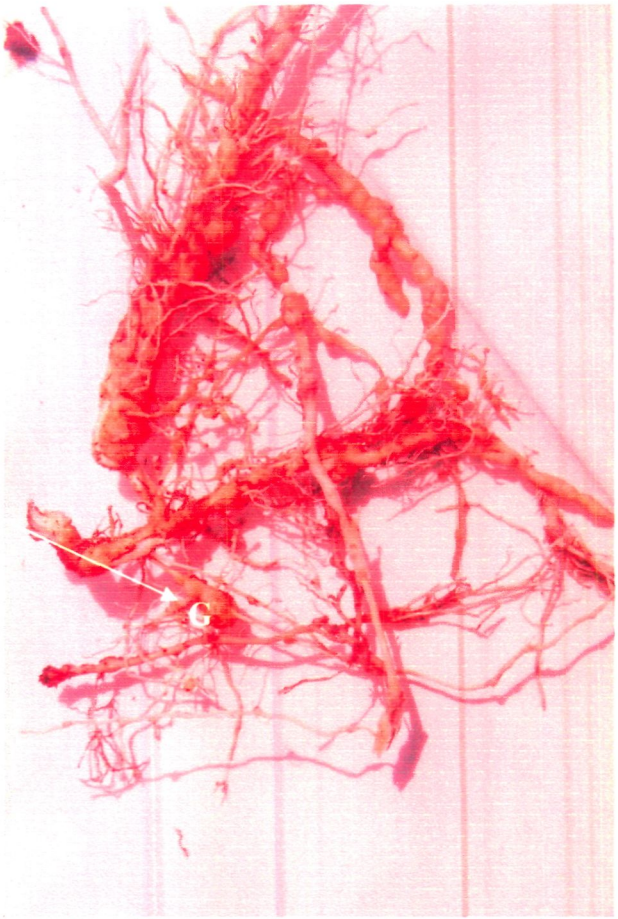


Fig. 1: Studies on the pathogenicity of *Meloidogyne incognita* on *Pseuderanthemum atropurpureum.*

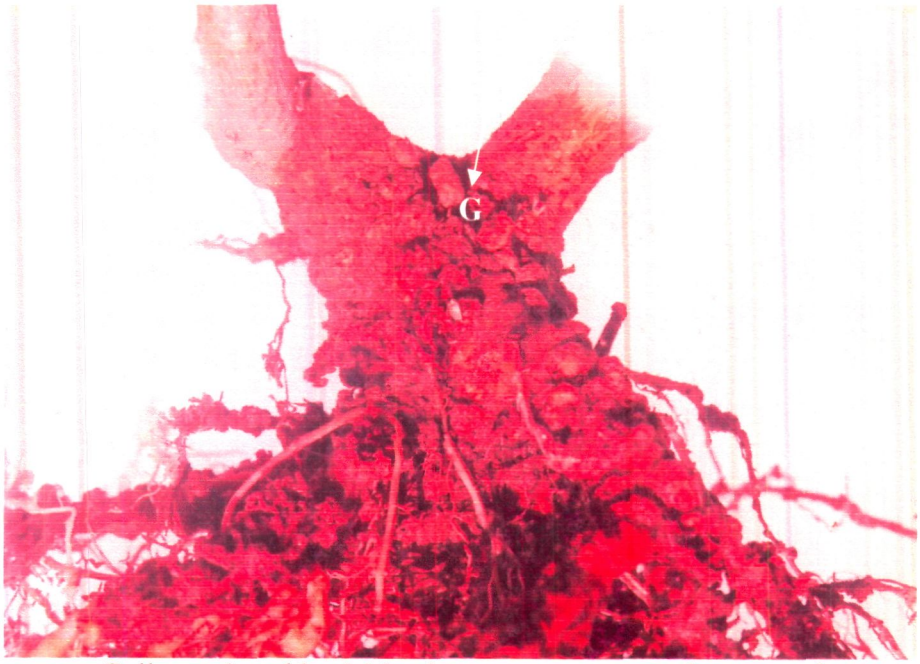


1- Control 2- 500 J_2 3- 1000 J_2
4- 2000 J_2 5- 4000 J_2 6- 8000 J_2

Fig. 1.1- Effect of different inoculum levels of *Meloidogyne incognita* on *Pseuderanthemum atropurpureum*.



Galls produced by *Meloidogyne incognita* on the roots of *Pseuderanthemum atropurpureum*.



Galls produced by *Meloidogyne incognita* on the stem of *Pseuderanthemum atropurpureum*.

STUDIES ON THE PATHOGENICITY OF *ROTYLENCHULUS RENIFORMIS* ON *COLEUS BLUMEI*

It is evident from the data presented in Table-4.1, Fig.2 and 2.1 that the reduction in plant growth characters (length, fresh and dry weight of the plant) of *Coleus blumei* was directly proportional to the inoculum levels of *Rotylenchulus reniformis* i.e. with increasing the inoculum levels from 500 to 8000 immature females of *R. reniformis* / kg soil, there was a corresponding increase in the reduction of plant growth characters. The inoculation of plants with 500, 1000, 2000, 4000 and 8000 immature females of *R. reniformis* / kg soil resulted in 3.7, 7.7, 25.4, 37.0 and 40.5 % reduction in plant growth, respectively as compared to control. However, the inoculum levels upto 1000 immature females / plant did not show significant reduction in plant growth characters as compared to control. Although, the significant reduction in plant growth was recorded at and above 2000 inoculum levels. Further, it was observed that the reduction in dry weight of the plant was not significant between the inoculum levels of 2000 and 4000 and 4000 and 8000 inocula. A significant linear relationship was found between the initial population 'Pi' and the final population 'Pf' of *R. reniformis.* The multiplication of

reniform nematode significantly reduced with the increase in the inoculum levels. The reproduction factor was highest (20.11) at the minimum inoculum level (500 immature females/kg soil) and lowest (5.57) at the maximum inoculum level (8000 immature females / kg soil). Thus, the rate of nematode multiplication showed a declining trend with the increasing in the initial inoculum levels suggesting it to be a density dependent phenomenon. It can be concluded from these results that the damaging threshold level of *R. reniformis* on *C. blumei* was found as 2000 immature females/ kg soil (Table-4.2).

Rotylenchulus reniformis is a sedentary semi-endoparasite of roots. The roots infected with *R. reniformis* showing moderate discoloration with the root-lets as dark brown and sometimes necrotic. The infection often results in pruning of roots. A severe curling of young roots of the plants were also observed at the highest inoculum level. Similarly, the plants inoculated with highest inoculum level of *R. reniformis* showing drying of leaf started from the margin within one month of post infection period. Thereafter, the drying of leaves spread gradually from the margin to mid-rib region followed by premature shedding of some leaves. Overall

Table-4.1: Studies on the pathogenicity of *Rotylenchulus reniformis* on *Coleus blumei.*

Inoculum levels	Plant length (cm)			Plant fresh weight (g)			Plant dry weight (g)			Percentage reduction over control
	Shoot	Root	Total	Shoot	Root	Total	Shoot	Root	Total	
0	62.1	29.2	91.3	102.0	42.1	144.1	34.2	10.9	45.1	-
500	61.7	27.7	89.4	99.5	40.2	139.7	33.0	10.4	43.4	3.7
1000	60.5	27.1	87.6	96.2	39.1	135.3	32.2	9.4	41.6	7.7
2000	50.8	22.5	73.3	79.0	32.1	111.1	26.3	7.3	33.6	25.4
4000	42.8	19.5	62.3	67.5	26.4	93.9	21.8	6.6	28.4	37.0
8000	40.9	17.4	58.3	64.4	24.5	88.9	20.4	6.4	26.8	40.5
C.D. (P=0.05)			9.20			12.27			6.05	
C.D. (P=0.01)			14.42			19.24			9.48	

Table-4.2: Effect of different inoculum levels on the multiplication of *Rotylenchulus reniformis* in *Coleus blumei.*

Inoculum levels	Nematodes/kg soil	Females/root system	Total	Reproduction factor (R=Pf/Pi)
500	9978	79	10057	20.11
1000	17149	120	17269	17.26
2000	26090	191	26281	13.14
4000	41061	264	41325	10.33
8000	44218	352	44570	5.57
C.D. (P=0.05)				1.74
C.D. (P=0.01)				2.88

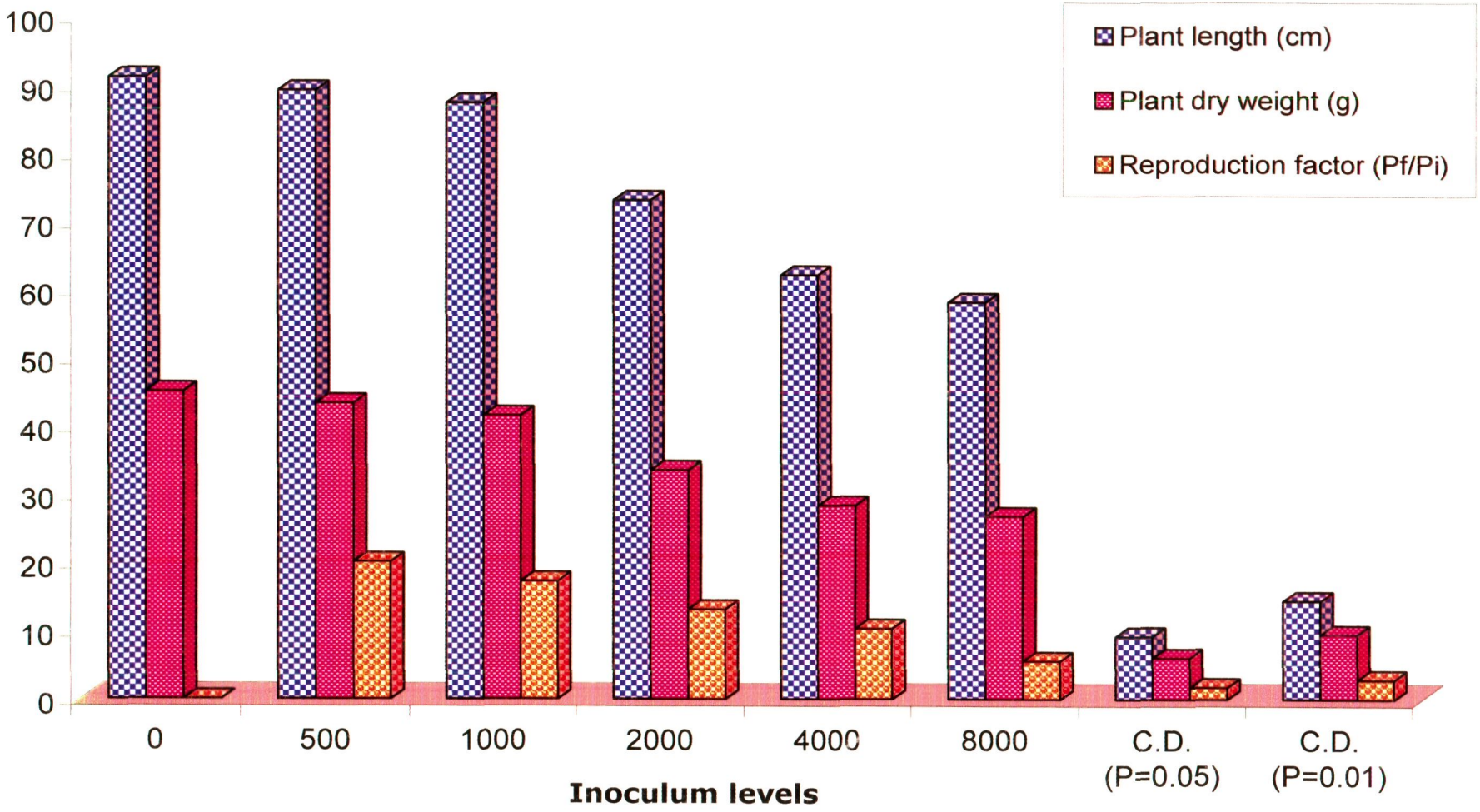


Fig. 2: Studies on the pathogenicity of *Rotylenchulus reniformis* on *Coleus blumei*.

1- Control 2- 500 IF 3- 1000 IF

4- 2000 IF 5- 4000 IF 6- 8000 IF

Fig. 2.1: Effect of different inoculum levels of *Rotylenchulus reniformis* on *Coleus blumei.*

the plants showing stunted plant growth parameters. It is interesting to note that the severity of the above symptoms increase with the increase in the inoculum levels.

STUDIES ON THE PATHOGENICITY OF *HELICOTYLENCHUS DIHYSTERA* ON *CELOSIA CRISTATA*

The data presented in Table-5.1, Fig.3 and 3.1 clearly indicated that the growth parameters of *Celosia cristata* significantly increased in the plants inoculated with 500 and 1000 gravid females/kg soil. The percentage of improvement in plant growth was +7.3 and +11.2 recorded in the corresponding treatments as compared to uninoculated plants. Moreover, the reduction in plants growth parameters was observed at and above 2000 inoculum levels. The reduction in the plant growth was -2.1, -22.0 and -34.8 observed in the plants inoculated with 2000, 4000 and 8000 gravid females/kg soil, respectively. However, the significant reduction in plants growth parameters was noticed at and above 4000 inoculum levels.

A significant linear relationship was observed between initial and final nematode population. The reproduction factor of *H. dihystera* was highest (40.4) when the inoculum level was lowest (500 gravid females / plant) but, lowest (5.6)

when inoculum level was highest (8000 gravid females / plant). It can be concluded from these results that the damaging threshold level of *H. dihystera* on *C. cristata* was observed as 4000 gravid females / kg soil (Table-5.2).

H. dihystera is a sedentary, semi-endoparasite of roots which penetrates more deeply into the roots and sometimes completely embedded in the cortex. Cells may become brown and necrotic around the nematode as a resulting of their feeding. *H. dihystera* produced small discrete relatively shallow necrotic lesions on the roots of *C. cristata.* The infected roots were irregularly and abnormally sparse. Secondary and tertiary rootlets were generally absent and the primary roots were blunt, malformed and showing stunted overall root growth. Feeding of nematodes resulted in chlorosis of leaves and reduction in plant growth parameter. It is interesting to note that the severity of the above symptoms increase with the increase in the levels from 4000 to 8000 gravid females / kg soil.

Table- 5.1: Studies on the pathogenicity of *Helicotylenchus dihystera* on *Celosia cristata.*

Inoculum levels	Plant length (cm)			Plant fresh weight (g)			Plant dry weight (g)			Percentage reduction over control
	Shoot	Root	Total	Shoot	Root	Total	Shoot	Root	Total	
0	74.4	29.6	104.0	149.0	52.0	201.0	47.2	13.0	60.2	-
500	85.0	30.7	115.7	164.5	55.7	220.2	52.2	12.4	64.6	+7.3
1000	87.6	32.4	120.0	171.0	56.4	227.4	55.0	12.0	67.0	+11.2
2000	73.1	29.1	102.2	145.2	49.2	194.4	46.7	12.2	58.9	-2.1
4000	63.3	22.4	85.7	118.7	41.0	159.7	37.2	9.7	46.9	-22.0
8000	55.1	19.0	74.1	105.7	29.4	135.1	31.0	8.2	39.2	-34.8
C.D. (P=0.05)			8.65			12.00			2.36	
C.D. (P=0.01)			13.56			18.82			3.70	

Table-5.2: Effect of different inoculum levels on the multiplication of *Helicotylenchus dihystera* in *Celosia cristata.*

Inoculum levels	Nematodes/kg soil	Females/root system	Total	Reproduction factor (R=Pf/Pi)
500	20121	80	20201	40.4
1000	24859	138	24997	24.9
2000	32750	164	32914	16.4
4000	40120	204	40324	10.0
8000	44918	252	45170	5.6
C.D. (P=0.05)				3.27
C.D. (P=0.01)				5.42

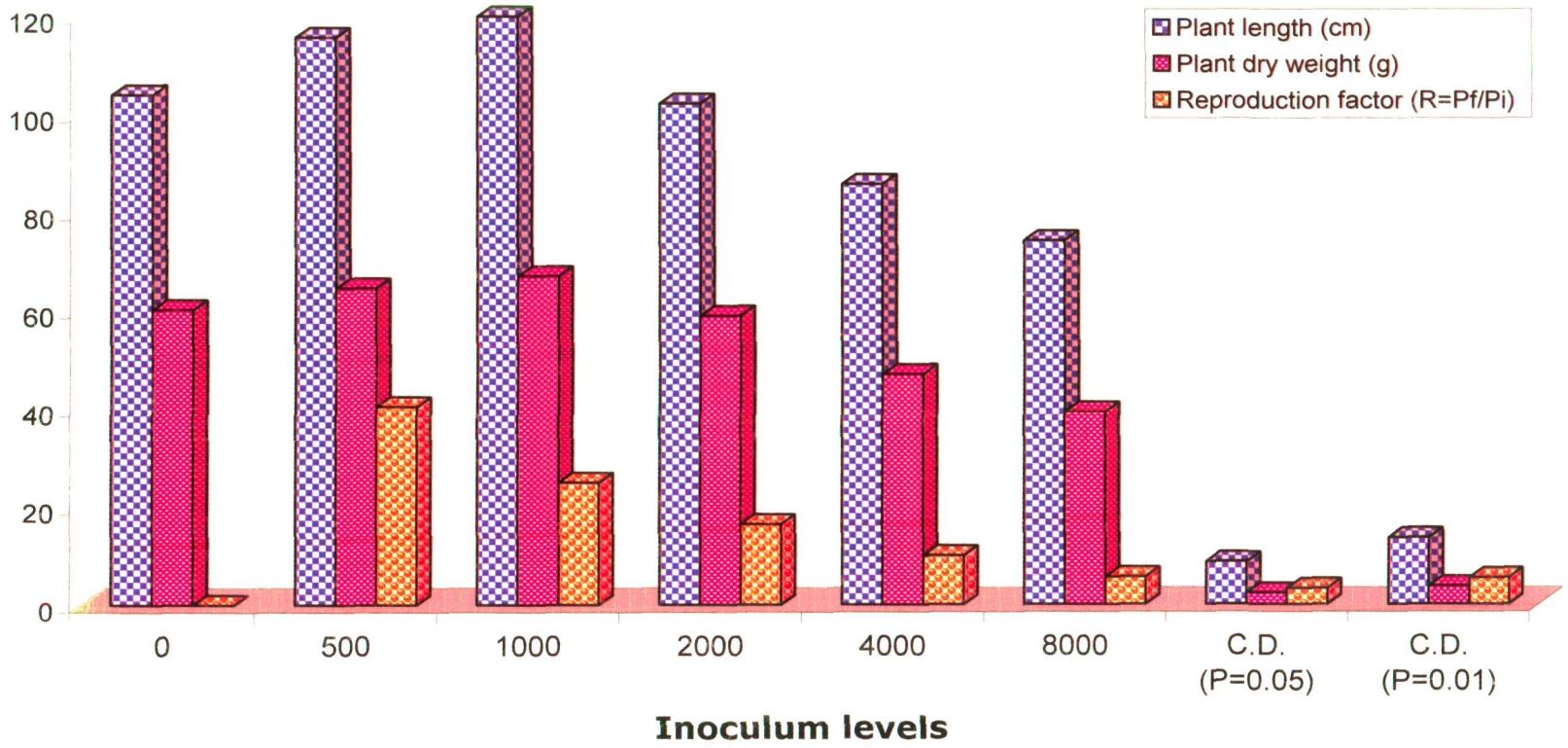


Fig. 3: Studies on the pathogenicity of *Helicotylenchus dihystera* on *Celosia cristata*.

1- Control 2- 500 GF 3- 1000 GF

4- 2000 GF 5- 4000 GF 6- 8000 GF

Fig. 3.1- Effect of different inoculum levels of *Helicotylenchus dihystera* on *Celosia cristata.*

Discussion

DISCUSSION

The perusal of results presented in Tables- 1.1 to 1.3, clearly indicated that nine plant parasitic nematode genera viz. *Aphelenchoides* sp., *Hoplolaimus* sp., *Meloidogyne* sp., *Pratylenchus* sp., *Rotylenchulus* sp., *Tylenchorhynchus* sp., *Tylenchus* sp. and *Xiphinema* sp. were encountered during the survey of ornamental plants grown in A.M.U. campus. The results showed that ornamentals are favourite hosts to plant parasitic nematode particularly *Meloidogyne* sp., *Helicotylenchus* sp. and *Hoplolaimus* sp. on the basis of prominence value. It was also noticed that the root-knot nematode found in high frequency and widely distributed. The highest density of root-knot nematode, *Meloidogyne* sp. was observed in the field having ornamental plant, *Althea rosea* (150/200cm^3 soil) and lowest in *Tagetes erecta* (25 / 200 cm^3 soil). Similarly, maximum density of reniform nematode, (*R. reniformis*) was observed in *Chrysanthemum indicum* (53/200cm^3 soil) and minimum in case of *Salvia splendens and Mirabilis jalapa* (12/ 200 cm^3 soil). The spiral nematode, *Helicotylenchus* was found in highest number in field having *Althea rosea* (119/200 cm^3 soil) whereas, its lowest density

was recorded in *Tagetes erecta* (20/200 cm^3 soil). The highest density of stunt nematode, *Tylenchorhynchus* was found in *Plumeria alba* (90/200cm^3 soil) and lowest density was recorded in *Celosia cristata* and *Salvia splendens* (10/200cm^3 soil). The maximum density of lance nematode, *Hoplolaimus* was recorded in *Althea rosea* (72/200cm^3 soil) and minimum density was recorded in *Coleus blumei* (15/200cm^3soil). *Tylenchus* and *Xiphinema* were found in higher number (84/200cm^3 soil and 40/200cm^3 soil) in *Althea rosea*. The density of *Pratylenchus* was highest (40/200cm^3 soil) in *Iberis amara* and *Jasminum sambac*. The maximum density of *Aphelenchoides* (44/200cm^3 soil) was recorded in *Althea rosea and* minimum (4/200cm^3 soil) in *Tagetes erecta.*

It is clearly confirm from the results that the diversity and the population of the nematodes in all the soil samples taken were non-uniform. Fluctuation in population of certain nematode genera might be due to soil types having different physico-chemical characteristics. These results are also in agreement with those of (Saba *et al.,* 2003) who reported that the diversity of the nematodes was found to be fluctuated at different times, at different stages of plants and in soils having different type of the plants.

The frequency and density alone will not give a precise idea of the prominence of nematode species since long term ecological merits are limited and hence Beals (1960) proposed prominence value by combining the above two parameters. Maximum prominence was recorded in *Meloidogyne* sp. (386.7) and lowest in *Xiphinema* sp. (27.0) (Table-1.3). Beside plant parasitic nematodes, some species of saprozoic nematodes were also found associated with the ornamental plants.

The highest absolute frequency, relative frequency, relative density and prominence value were recorded for the root-knot nematode. This might be due to polyphagous nature of the nematode and presence of suitable hosts in the ornamental beds almost throughout the year. Therefore, the root-knot nematode emerged as the most important nematode in the region among plant parasitic nematode. Most of the ornamental plants infected with root-knot, reniform and spiral nematodes were showing symptoms of yellowing, stunting and patchy growth. Thus the present investigations have clearly indicated that the association of plant parasitic nematodes, especially the most important ones like root-knot, reniform and spiral nematodes which are highly pathogenic in

nature.Therefore, their occurrence in high densities may pose a serious threat to some ornamental plants, if the management practices are not being governed to keep the populations under check. Hence it needs immediate attention of the growers and researchers.

The results presented in Table-2.1 clearly indicated that highest percentage of infection of root-knot nematodes, (*Meloidogyne* spp.) was observed in *Impatiens balsamina* (100.0) and lowest in *Cosmos bippinatus* (14.0). Out of 29 plants infected with *Meloidogyne* spp., 27 plants were found to be infected with *M. incognita* followed by 20 and 9 plants were infected with *M. javanica* and *M. arenaria,* respectively. Among the *Meloidogyne* spp., the highest percentage of infection caused by *M. incognita* was observed in *Pseuderanthemum atropurpureum* (80.0) and lowest in *Dianthus caryophyllus* (5.0), whereas, highest percentage of infection of *M. javanica* and *M. arenaria* was observed in *Mirabilis jalapa* (72.0) and *Celosia cristata* (28.0) and lowest in *Phlox drummondii* (7.0) and *Althea rosea* (6.0), respectively. The maximum number of galls produced by *M. incognita, M. javanica* and *M. arenaria* were observed in *P. atropurpureum* (102.4), *I. balsamina* (70.2) and *C. cristata* (37.0), respectively.

Similarly, in case of *Rotylenchulus reniformis,* only 15 species of ornamental plants were found to be infected with reniform nematode. The highest percentage of infection of *R. reniformis* was observed in *Hibiscus rosa-sinensis* (56.0) and lowest in *Althea rosea* (8.0). Moreover, the highest number of females of reniform nematode/ root system was recorded in *Dahlia variabilis* (62) and lowest in *Althea rosea* (22).

A perusal of the literature revealed that *M. incognita* has not been reported so far on *Pseuderanthemum atropurpureum* from anywhere (Goodey *et al.,* 1965; Sitaramaiah, 1984; Singh and Sharma, 1998). Therefore, this constitutes the first report of the incidence of *Meloidogyne incognita on P.atropurpureum.* Similarly, the scanning of literature revealed that there are some ornamentals which are recorded as new hosts of *Meloidogyne* spp. viz. *M. incognita (Iberis amara, Plumeria alba), M. javanica (Althea rosea, Amaranthus caudatus, Bryophyllum pinnatum, Calendula officinalis, Cosmos bipinnatus, Jasminum sambac, Kochia scoparia), M. arenaria (Dianthus caryophyllus, Helianthus annus, Hibiscus rosa-sinensis)* from India.

The results presented in Table -2.1 clearly showed that out of 15 plants, 8 plants (*Chrysanthemum indicum, Hibiscus*

rosa-sinensis, Jasminum sambac, Kochia scoparia, Rosa indica and *Thevetia peruviana*) were already known as host for reniform nematode. Whereas, out of the 8, the 4 plants viz. *Calendula officinalis, Dianthus caryophyllus, Impatiens balsamina* and *Petunia hybrida* were recorded as new host for reniform nematode from India. Further, it is interesting to note that the 3 plants viz. *Althea rosea, Coleus blumei* and *Plumeria alba* were so far not recorded as host for reniform nematode from the world.

To determine the inoculum threshold level of root-knot nematode *(M. incognita),* the seedlings of *Pseuderanthemum atropurpureum* were inoculated with different inoculum levels of *M. incognita* (500, 1000, 2000, 4000 and 8000 J_2/plant). The result presented in Table-3.1 and 3.2, Fig.1 and 1.1 clearly showed that there was a significant reduction in plant growth parameters at 1000 or more second stage juveniles/kg soil. These results showed that the inoculum threshold level of *M. incognita* on *P. atropurpureum* was 1000 J_2/ kg soil. At this level, symptoms like thinly spread foliage with small leaves, premature shedding of leaves and also stunting of plants, were also recorded. Significant reduction in plant growth characters due to *M. incognita* at or above 1000 inoculum is in agreement

with the findings of Reddy (1981), Tyagi and Alam (1988), Gupta and Mehta (1989) and Mohan and Mishra (1996). Our results varied from that of Thankamony *et al.* (1996), Mohandas and Ramakrishnan (1997), Kalita and Phukan (1993) and Raut (1980) who demonstrated that the damaging threshold level of *M. incognita* was 20, 100, 200 and 2000 J_2/kg soil on different crops.

It was also observed that with an increase in the level of inoculum there was a progressive increase in host infestation. Rate of nematode multiplication decreased as the inoculum levels of nematode increased, may be due to competition for food and space. Surface area of root remained same for both lower and higher inoculum levels. Overcrowding of nematodes at higher inoculum density created competition among the nematodes which resulted in their natural death and reduced multiplication. The high rate of multiplication at low inoculum levels could possibly be due to positive factors like abundance of food, lack of competition and the ability of host to support these levels of population. According to Oostenbrink (1966), the increase in the nematode populations and the reduction in yield of crop are directly influenced by the initial density of the nematodes in the soil. His view holds true with the present

findings where plant growth was proportionately affected with increase in the number of galls and final nematode population. The progressive decrease in plant growth and multiplication of nematode with the increasing inocula of root-knot nematode on different crops have also been reported by (Seinhorst, 1960; Raut and Sethi, 1980; Khan and Hussain, 1989; Meena and Mishra, 1993; Fazal *et al.*,1994; Ramakrishnan *et al.*,1994; Pathak *et al.*, 2000; Khan and Ashraf, 2006). It can be concluded from the above results that the damaging threshold level of *M. incognita* on *P. atropurpuruem* was 1000 J_2/plant.

To determine the inoculum threshold level of *Rotylenchulus reniformis,* the *Coleus blumei* was inoculated with different inoculum levels of *R. reniformis* (500, 1000, 2000, 4000 and 8000 immature females / kg soil). The results presented in Tables-4.1 and 4.2, Fig.2 and 2.1 clearly showed that there was a significant reduction in plant growth characters of *C. blumei* at and above 2000 inoculum levels. Moreover, it was also observed that the reduction in dry weight of the plant was not significant between the inoculum levels of 2000 and 4000 and 4000 and 8000 immature females / kg soil. These results expressing minimum pathogenic level

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(2000 immature females / kg soil) of *R. reniformis* on *C. blumei* .These findings are also in agreement with those of Swarup and Dasgupta (1986), Khan and Dar (2002) and Khan and Ashraf (2005) who also reported that the damaging threshold level of *R. reniformis* on different crops was 2000 immature females / kg soil. Moreover, my results are not in agreement with those of Gupta and Yadav (1979), Singh and Khera (1979), Thakar and Yadav (1985) and Padhi and Misra (1987) who reported that the damaging threshold level of *R. reniformis* vary between 100 to 1000 inoculum level on different crops. This variation may be possibly either due to different crop plants used and /or changed in experimental conditions.

It was also observed that with increase in the inoculum levels of *R. reniformis* there was corresponding decrease in the rate of nematode multiplication. The reason for the reduction in nematode multiplication with increasing inoculum levels may be due to possible occurrence of antagonism since the root surface area for both the lower and higher inoculums remained the same, crowding of nematodes at higher inoculum densities created natural death and reduced multiplication (Triantaphyllou 1960; Davide and Triantaphyllou, 1967). The

progressive decrease in the plant growth and nematode multiplication with the increasing inocula of nematode has also been reported by Khan (1981), Shekhar *et al.* (1996) Vats and Dalal (1988) on different crops.

Similarly, to find out the inoculum threshold level of spiral nematode (*Helicotylenchus dihystera*), the seedling of *Celosia cristata* were inoculated with different inoculum levels of *H. dihystera* (500, 1000, 2000, 4000 and 8000 gravid females/Kg soil). The results presented in Table-5.1 and 5.2, Fig.3 and 3.1 clearly indicated that there was a significant increase in plant growth parameters at lower inocula i.e. 500 and 1000 gravid females / kg soil as compared to control. The increased in plant growth parameters of *C. cristata* might be due to some stimulatory factors such as root degeneration i.e. destruction of root tips or tissues by the nematodes may elicit the formation of new roots without the new roots influencing any control over the number of root damage and / or increased production of growth hormones. These results are also in agreement with those of Wallace (1971) and Muthukrishanan *et al.* (1975). The significant reduction in plant growth parameters occur at and above 4000 inoculum levels. My results are also in confirmity with those of Firoza

and Maqbool (1995) who reported the damaging threshold level of *H. dihystera* was 4000 nematodes/kg soil on brinjal, tomato and wheat. Similarly, at this level, symptoms like chlorosis, stunted growth and sparsely developed root were observed by them in these plants. However, my results are contradictory with those of Rao and Swarup (1974), Sartaj *et al.* (1999) and Kumar and Singh (2007) who reported that the damaging threshold level of *H. dihystera* varied between 500 to 5000 on different crops.

Moreover, Summer (1967) in his studies with blue grass (*Poa pratensis*) was not able to demonstrate the pathogenic effect of *H. dihystera* in glasshouse or laboratory tests. Churchill *and* Ruehle (1971) stated that the nematode had little or no effect on tap root weight of sycamore (*Platanus occidentalis*). Similarly no pathogenic effect of *H. dihystera* was observed on *P. palustris* by Ruehle (1972). Rao and Swarup (1974) have observed that okra and tomato did not support the nematode population. Though, Orbin (1973) noticed the endo-ectoparastic habit of the spiral nematode on the roots of soybean, he did not observe the pathogenic effect of the nematode on the plants. Observations made in turf bombling greens (*Agrosia temics*) in Adelaide by Wallace

(1971) had shown however that *H. dihystera* was an important factor in causing patchiness in the bombling greens and the number of nematode were significantly correlated with the spatial distribution of the damaged turf. Rao and Swarup (1974) have also reported that an initial population density of 1000 nematodes / 500 g of soil caused significant reduction in the fresh weight of shoots, roots and canes over inoculated.

The plant growth parameters viz. length and weight of plant significantly reduced at 4000 inoculum level. This might be due to mechanical injury to the root-cortex after feeding and indirectly disturbed the normal physiology of the plants. The abnormal changes in the host physiology restrict the movement of the food materials and caused mineral deficiencies (Malakeberhan *et al.*, 1985; Haider *et al.*, 1987).

The gradual reduction of plant growth with increasing inoculum level might be correlated with the decreasing concentration of Mn, Fe and Zn in leaves. Zn plays an important role in auxin synthesis. (Huber, 1978; Skoog, 1940). Hence, the low concentration of Zn may have contributed in slow plant growth. Similarly, Mn and Fe participate in chlorophyll synthesis. Their reduced values could

be responsible for pale yellow as well as chlorotic conditions of the leaves ultimately affecting photosynthesis.

It was also observed that with the increase in the inoculum levels of *H. dihystera* there was corresponding decrease in the rate of nematode multiplication. Increase in population decreases the availability of the food, and increases the nematode interactions such as toxic effects of excretory products or competition for sites suitable for feeding. These factors in turn may affect development of the nematode and hence the rate of increase. The progressive decrease in the nematode multiplication with the increasing inocula of nematode has also been reported by Sartaj *et al.* (1999), and Kumar and Sigh (2007).

From the above results, it can be concluded that the damaging threshold level of *M. incognita* on *P. atropurpureum* was 1000 J_2 / kg soil, *R. reniformis* on *C. blumei* was 2000 immature females / kg soil and *H. dihystera* on *C. cristata* was 4000 gravid females / kg soil. The information gathered from the present study may provide the base line for further research to develop appropriate strategies for the management of plant parasitic nematodes associated with ornamental plants.

Summary & Conclusion

SUMMARY AND CONCLUSION

Out of 144 soil samples collected from 18 ornamental plants from different area of Aligarh Muslim University, total nine genera of plant parasitic nematodes were found to be associated with ornamental plants. Among these, root-knot nematode has been detected in higher frequency in ornamental plants. It was observed that the high density of root-knot nematode (*Meloidogyne* sp.), reniform nematode (*Rotylenchulus* sp.), spiral nematode (*Helicotylenchus* sp.), stunt nematode (*Tylenchorhynchus* sp.), lance nematode (*Hoplolaimus* sp.), dagger nematode (*Xiphinema* sp.), lesion nematode (*Pratylenchus* sp.), *Tylenchus* sp. and foliar nematode (*Aphelenchoides* sp.) were observed in *Althea rosea* (150/200 cm^3 soil), *Chrysanthemum indicum* (53/200 cm^3 soil), *Althea rosea* (119/200 cm^3 soil), *Plumeria alba* (90/200 cm^3 soil), *Althea rosea* (72/200 cm^3 soil), *Althea rosea* (40/200 cm^3 soil), *Iberis amara* and *Jasminum sambac* (40/200 cm^3 soil), *Althea rosea,* (84/200 cm^3 soil), and *Althea rosea* (44/200 cm^3 soil), respectively. However, the lower density of root-knot nematode (*Meloidogyne* sp.), reniform nematode (*Rotylenchulus* sp.), spiral nematode

(*Helicotylenchus* sp.), stunt nematode (*Tylenchorhynchus* sp.), lance nematode (*Hoplolaimus* sp.), dagger nematode (*Xiphinema* sp.), lesion nematode (*Pratylenchus* sp.), *Tylenchus* sp. and foliar nematode (*Aphelenchoides* sp.) were observed *in Tagetes erecta* (25 /200 cm^3 soil),*Mirabilis jalapa* and *Salvia splendens* (12/200 cm^3 soil), *Tagetes erecta* (20/200 cm^3 soil), *Celosia cristata* and *Salvia splendens* (10/200 cm^3 soil), *Coleus blumei* (15/200 cm^3 soil), *Mirabilis jalapa* (6/200 cm^3 soil), *Hibiscus rosa-sinensis* and *Tagetes erecta* (12/200 cm^3 soil), *Iberis amara* and *Petunia hybrida* (6/200cm soil) and *Tagetes erecta* (4/200 cm^3 soil), respectively. Maximum prominence value was recorded in case of *Meloidogyne* sp. (386.7) and minimum in *Xiphinema* sp. (27.0). Besides plant parasitic nematodes, some saprozoic nematodes were also found to be associated with the ornamental plants. Most of the ornamentals infected with root-knot, reniform and spiral nematodes were showing symptoms of yellowing, stunting and patchy growth. Thus the root-knot nematode emerged as an important nematode in the A.M.U.campus where ornamental plants are grown.

It can be concluded from the present investigations that the association of plant parasitic nematodes, especially the

most important ones like root-knot, reniform and spiral nematodes which are highly pathogenic in nature. Therefore, their occurrence in high densities may pose a serious threat to some ornamental plants, if the management practices are not being governed to keep the nematode populations under check. Hence, it needs immediate attention of the growers and researchers.

Out of 50 species of ornamental plants studied, 29 species of ornamental plants were found to be infected with root-knot nematodes (*Meloidogyne* spp.) and 15 were infected with *Rotylenchulus reniformis.* The highest infection of root-knot nematodes (*Meloidogyne* spp.) and *R. reniformis* was observed in *Impatiens balsamina* and *Hibiscus rosa-sinensis,* respectively. Similarly, out of 29 ornamentals found to be infected with *Meloidogyne* spp., 27 plants were infected with *M. incognita,* whereas, 20 and 9 plants were infected with *M. javanica* and *M. arenaria,* respectively.

The maximum number of galls produced by *M. incognita, M. javanica* and *M. arenaria* were observed in *Pseuderanthemum atropurpureum* (102.4), *Impatiens balsamina* (70.2) and *Celosia cristata* (37.0) respectively. However, on the other hand, the highest number of females of

reniform nematode per root system was recorded in *Dahlia variabilis* (62), whereas, the minimum number of females was recorded in *Althea rosea* (22). The frequency of occurrence of root-knot nematode and reniform nematode in ornamental plants were recorded as 58 and 30%, respectively.

A review of pertinent literature revealed that there are some ornamentals which are recorded as new hosts of *Meloidogyne* spp.viz. *M .incognita* (*Iberis amara and Plumeria alba*), *M. javanica* (*Althea rosea, Amaranthus caudatus, Bryophyllum pinnatum, Calendula officinalis, Cosmos bipinnatus, Jasminum sambac* and *Kochia scoparia), M. arenaria* (*Dianthus caryophyllus, Helianthus annus and Hibiscus rosa-sinensis*) from India.

The reduction in plant growth characters of *Pseuderanthemum atropurpureum* was directly proportional to the inoculum levels from 500 to 8000 of second stage juveniles of *M. incognita* (J_2), per plant. There was a corresponding increase in the reduction of plant growth characters of *P. atropurpureum* with an increase in the inoculum. Although, the significant reduction in plant growth was recorded at and above 1000 J_2/ plant. Further, it was observed that the reduction in plant growth characters was not

significant between the inoculum levels of 2000 and 4000 J_2 and, 4000 and 8000 J_2/ plant.

It was also observed that with an increase in the level of inoculum there was a progressive increase in the host infestation as indicated by the number of galls as well as the population buildup of nematodes. Moreover, the rate of nematode multiplication was reduced with the increase in the inoculum density of *M. incognita.*

The reduction in plant growth parameters of *Coleus blumei* was directly proportional to the inoculum levels of *Rotylenchulus reniformis.* However, the inoculum levels up to 1000 immature females/kg soil did not show significant reduction in plant growth parameters as compared to control. Although, the significant reduction in plant growth parameters was recorded at and above 2000 immature females/kg soil. It was also observed that with the increase in inoculum levels of *R. reniformis,* the rate of nematode multiplication was reduced.

The growth parameters of *Celosia cristata* significantly increased in the plants inoculated with 500 and 1000 gravid females of *Helicotylenchus dihystera*/kg soil as compared to control. Although, the significant reduction in plant growth

parameters was noticed at and above 4000 inoculum levels. There was no significant variation in plant growth parameters in the plants inoculated with 2000 gravid females/kg soil as compared to control. It was observed that the rate of nematode multiplication was reduced with the increase in the inoculum density of *H. dihystera.*

It can be concluded from the above results that the damaging threshold level of *M. incognita* on *P. atropurpureum* was 1000 J_2 / plant, whereas, *R. reniformis* on *C. blumei* was 2000 immature females/ plant and that of *H. dihystera* on *C. cristata* was 4000 gravid females/ plant. The information gathered from the present study may provide the baseline for further research to develop appropriate strategies for the management of these nematodes in ornamentals.

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